

FOR OFFICIAL USE ONLY

JPRS L/9881

31 July 1981

# Translation

AEROSPACE MEDICINE

SIXTH ALL-UNION CONFERENCE

ON SPACE BIOLOGY AND AEROSPACE MEDICINE

KALUGA 5-7 JUNE 1979

Part I



FOREIGN BROADCAST INFORMATION SERVICE

FOR OFFICIAL USE ONLY

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [ ] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

COPYRIGHT LAWS AND REGULATIONS GOVERNING OWNERSHIP OF MATERIALS REPRODUCED HEREIN REQUIRE THAT DISSEMINATION OF THIS PUBLICATION BE RESTRICTED FOR OFFICIAL USE ONLY.

FOR OFFICIAL USE ONLY

JPRS L/9881

31 July 1981

AEROSPACE MEDICINE  
SIXTH ALL-UNION CONFERENCE ON SPACE BIOLOGY AND AEROSPACE MEDICINE  
KALUGA 5-7 JUNE 1979  
PART I

Complete translation of the Russian language book edited by Academician O. G. Gazenko: "Aviakosmicheskaya meditsina. VI Vsesoyuznaya konferentsiya po kosmicheskoy biologii i aviakosmicheskoy meditsine. Kaluga 5-7 iyunya 1979. Chast' I", USSR Ministry of Health, Department of Physiology of the USSR Academy of Sciences, Institute of Biomedical Problems of the USSR Ministry of Health and State Museum of History of Cosmonautics imeni K. E. Tsiolkovskiy, published in Moscow, 160 pages [summaries of papers]

CONTENTS

Experimental Physiological Studies

Results of Medical Examination of Cosmonauts During Flight Aboard the Salyut-6 Orbital Station .....	1
Gravity and Cerebral Circulation .....	3
Oxygenation of Human Tissues During Space Flights Aboard the Salyut-6 Orbital Station .....	4
Regulation of Regional Hemodynamics During Long-Term Space Flights .....	6
Results of Electrocardiographic Examination of Cosmonauts During Flight Aboard the Salyut-4 Orbital Station .....	8
Study of Hemodynamic Effects of Weightlessness in Ground-Based Model Experiments .....	10
Analysis of Changes in Diastolic Phases of the Right and Left Ventricles During 140-Day Space Flight of Cosmonauts Aboard an Orbital Station .....	12
Temperature Regulation in Weightlessness .....	13
Evaluation, Prediction and Optimization of Cosmonauts' Efficiency During Flight Aboard the Salyut-6 Orbital Station .....	14
Effect of 140-Day Space Flight on Motor System and System of Regulation of Motor Functions .....	16
Microflora in the Crews of Space Stations .....	18
Microflora of the Upper Respiratory Tract of Crews Engaged in Long-Term Space Flights .....	20
Distinctions of Intestinal Dysbacteriosis in Cosmonauts Involved in Space Flights of Different Duration .....	22
Conditionally Pathogenic Enterobacteria as Possible Pathogens of Various Infectious Processes in Spacecraft Crews .....	24

- a -

[I - USSR - C FOUO]

FOR OFFICIAL USE ONLY

## FOR OFFICIAL USE ONLY

Study of Antiviral Immunity of the Crew of the Salyut-6 Space Station .....	26
Biological Properties of Lactobacilli Isolated From Cosmonauts	
Before and After Space Flights .....	28
Hormonal Status of Cosmonauts After Flight Aboard the Salyut-6	
Orbitai Station .....	29
Basic Problems of Man's Adaptation to Space Flight Conditions .....	31
Effects of Weightlessness and Earth-Based Simulation Thereof on	
Hemoglobin Synthesis in Man .....	32
Auditory Function of Man in the Presence of Transverse Accelerations .....	33
Study of Dynamics of Blood and Lymph Circulation in Man by	
Simulation Methods .....	35
Some Results of Studying the Human Cardiovascular System During	
Orthostatic Test Using Simulation Modeling .....	37
Biomechanics of Distribution of Ventilation-Perfusion Ratios in the	
Human Lungs Under the Influence of Gravity and Inertial Forces .....	39
Studies of Skeletal Muscles and Motor Function in Hypokinetic Animals	
and Man .....	41
Excretion of Cyclic Nucleotides in Urine Under Conditions of Altered	
Gravity .....	43
Hormonal Regulation of Fluid-Electrolyte Metabolism of Man	
During Long-Term Hypokinesia .....	45
Role of Volume Natriuretic Reflex in Changing Renal Excretion of Fluid	
and Electrolytes With Ground-Based Simulation of Weightlessness .....	47
Man's Body Temperature During Exercise Following Brief Bed Rest .....	48
Cytological Study of Peripheral Blood Erythrocytes and Leukocytes	
Following Brief Space Flights .....	50
Distinctions of Blood Lipoprotein Metabolism Related to Limited	
Motor Activity .....	52
Adaptive Changes in Cortical Neurons Under Hypokinetic Conditions .....	53
Plasma Renin Activity and Diuresis as Indicators of Changes in Homeostasis	
of Fluids During Simulation of Some Elements of Weightlessness With	
Accelerations .....	54
Effects of Space Flight Factors on Blood Protein Spectrum .....	56
Study of Some Functions in Man Related to Altered Daily Schedule .....	57
Changes in Human Body Temperature During Three-Hour Immersion in Water ....	59
Some Results of Physiological Experiments Conducted Aboard	
Cosmos Biosatellites .....	61
Methodology of Biological Experiments Aboard the Cosmos Series of	
Specialized Earth Satellites. Complexes of Life Support Systems	
and Scientific Research Equipment .....	63
Experiment With Artificial Gravity Aboard the Cosmos-936 Biosatellite .....	65
State of Higher Nervous Activity of Animals Following Flights	
Aboard Biosatellites .....	67
Electron Microscopic Study of Rat Pancreas After Space Flight	
Aboard the Cosmos-936 Biosatellite .....	69
Structure of the Small Intestinal Mucosa of Rats After Space Flight	
Aboard the Cosmos-936 Biosatellite .....	71
Ion Regulating Function of Animal Kidneys After Flight Aboard the	
Cosmos-936 Biosatellite .....	73
Effect of Flight Aboard the Cosmos-936 Biosatellite on Bioenergetics	
of Animals' Skeletal Muscles .....	75
Study of Contractile Function of Muscle Proteins on the Model of	
Glycerinated Fibers in an Experiment Aboard the Cosmos-936 Biosatellite .	77

- b -

FOR OFFICIAL USE ONLY



## FOR OFFICIAL USE ONLY

Effect of Artificial Gravity on Morphological Manifestations of Animal Reactions After Flight Aboard the Cosmos-936 Biosatellite .....	79
Experiments Conducted Aboard the Salyut-6 Orbital Station With Biological Objects .....	81
Effect of Clinostating of Etiolate Arabidopsis Seedlings on Some Parameters of Plant Fertility .....	82
Study of the Biological Effects of Space Factors on Representatives of the Animal Kingdom .....	83
Adaptation to Usual and Unusual Mechanical Conditions .....	85
The First Experiments in the USSR Dealing With the Study of the Effects of Accelerations .....	87
Effect of Long-Term +G <sub>z</sub> Accelerations on Efficiency and Some Physiological Parameters of Operators .....	89
Experimental Estimation of Blood Pressure and Blood in Vessels of the Lower Extremities of Man Exposed to Longitudinal Accelerations and Wearing a G Suit .....	91
Effect of +G <sub>x</sub> Accelerations on Corticosteroid Excretion .....	93
Experimental Theoretical Substantiation of an in <i>Vitro</i> Method of Evaluating the Dynamic Strength of the Human Spine .....	95
Endurance of Accelerations During Periods of Calm and Increased Solar Activity .....	97
Effect of Inflating G Suit on Some Parameters of Human Hemodynamics .....	99
Optimum Respiration During Long-Term Exposure to Transverse Accelerations .	101

## Clinicophysiological Studies, and Therapeutic-Preventive Measures

Main Aspects of the Rehabilitation Problem in Space Medicine .....	102
Rehabilitation and Therapeutic Measures Following 140-Day Space Flight ....	103
Pharmacological Stimulators of Physical Fitness in Space Medicine .....	105
Autogenic Correction of Cosmonaut's Condition in Flight .....	107
Cosmonaut Care in Orbit: Experience and Problems .....	108
Adverse Reactions in the Acute Period of Adaptation to Weightlessness, and the Problem of Prevention Thereof .....	110
Use of Negative Pressure for Diagnosis and Prevention of Circulatory Disorders During Space Flights .....	112
Electroneurolepsy (Electroanalgesia) as a Method of Preventing and Treating Functional Disorders in Cosmonauts During the Readaptation Period .....	114
Distinctive Features in Planning Physical Training During Long-Term Space Flights .....	116
Prevention of Physical Deconditioning of Man by Means of Regular Exercise .....	118
The Problem of Adaptation of the Circulatory System to Weightlessness ....	120
Problems of Refining Ground-Based Cosmonaut Training .....	121
Effect of Base Level of Physical Conditioning on Endurance of Limited Motor Activity .....	123
Efficacy of Preventive Measures During Hypokinesia, According to Stabilographic Data .....	125
Experimental Validation of a Set of Preventive Measures for Long-Term Manned Space Flights .....	127
Pharmacotherapy Using New Actoprotective Agents for Disturbances Caused by Long-Term Hypokinesia .....	129
The Problem of Assessing Degree of Adaptation to Long-Term Space Flight Conditions .....	130

- c -

FOR OFFICIAL USE ONLY

## FOR OFFICIAL USE ONLY

Special Breathing Exercises in the System for Conditioning Against the Adverse Factors of Long-Term Space Flights .....	132
Problems of Forecasting and Preventing Allergic Complications During Long-Term Space Flights .....	133
Existence of 'Resident Type' Carriers of Staphylococcus Aureus Among Cosmonauts Before Flights, and Some Measures for Prevention of Disease .	135
Some of the Results of the International 'Audio' Experiment Conducted in Flight Aboard the Salyut-6 Orbital Station .....	136
System of Medical Care for Cosmonauts During Flights Differing in Duration .....	137
Pathophysiological Aspects of Survival of Crews of Flying Vehicles After Emergency Landings in Cold Regions .....	139
Resuscitation and Anesthesiological Problems of Space Medicine .....	141
Effect of Hypokinesia on Regional Redistribution of Blood in the Presence of Traumatic Shock .....	143
The Phenomenon of Convergence of Cervicolabyrinthine Impulsation on Mechanisms of the Spinal Reflex System and Its Significance to the Characteristics of Vestibulocerebral Relations .....	145
Characteristics of Coordinating 'Adjustment' of the Central Nervous System in Studies of Postural Reactions .....	147
Study of the Pathogenesis of Motion Sickness .....	149
Study of the Pathogenesis of the Space Form of Motion 'Sickness' .....	151
Pathogenetic Basis for Development of Motion Sickness .....	153
Some Clinicophysical Aspects of Vestibular Disorders During Space Flights.	154
Function of Vestibular Analyzer in the Presence of Altered Cerebral Circulation .....	156
Statokinetic Stability and Fitness of Flight Personnel .....	157
Reflex Therapy as a Possible Means of Enhancing Resistance to Coriolis Accelerations .....	158
'Sanogenesis' of Vestibular Disorders .....	160
Pharmacological Prevention of Disorders Occurring Under the Cumulative Effect of Accelerations .....	161
Principles Involved in the Approach and Choice of Agents for the Prevention and Treatment of Motion Sickness in Orbital Flight .....	163
Complex Method for Enhancing Vestibular Stability .....	165
Role of Vestibular Analyzer in Adaptation to Adverse Environmental Factors	166
Significance of Trophics of the Vestibular System in the Mechanism of Vestibulosomatic and Vestibulovegetative Reactions of Equilibrium Organs	168
Effect of Body Position on Regional Neurovasomotor Reactions of Pulmonary Circulation .....	170
Distinctions of Vestibular Reactions as a Function of Intensity of Stimulus and State of the Organism .....	171
Brain Tissue Oxygen Tension in Hypoxic Rats .....	172
Changes in Gas Exchange and Some Functional Parameters in Rats Submitted to Long-Term Hypokinesia .....	174

- d -

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

EXPERIMENTAL PHYSIOLOGICAL STUDIES

RESULTS OF MEDICAL EXAMINATION OF COSMONAUTS DURING FLIGHT ABOARD THE SALYUT-6 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 5-6

[Article by O. G. Gazenko, S. A. Gozulov, Yu. G. Nefedov, A. V. Beregovkin, I. I. Bryanov, A. D. Yegorov, V. A. Degtyarev, V. V. Kalinichenko and I. I. Kas'yan]

[Text] The main medical tasks related to the manned missions on the Salyut-6 program consisted of maintaining the crews' good health status and high efficiency during and after the flight, as well as studying phenomenology and mechanisms of changes in the body's reactions during different stages of adaptation to flight conditions and evaluation of the efficacy of preventive measures used.

On the whole, the changes observed during the flight conformed with the preflight predictions and reflected the phasic nature of adaptation processes. They were manifested by symptoms of redistribution of blood, positional changes on the electrocardiogram, fluctuations of main hemodynamic parameters in flight, which did not exceed the physiological range, increased pulsed delivery of blood to the head and diminished circulation in the leg. The circulatory reactions to the physical load and effect of negative pressure varied as well with increase in duration of flight, and they were characterized by a tendency toward relative stabilization.

The changes observed after the flight were consistent with systemic reactions inherent in the readaptation period.

These reactions were functional, and qualitatively they did not differ from the reactions observed in previous flights.

They were manifested by several syndromes, the chief ones being general fatigue and asthenization of the body; deconditioning for orthostatic and physical factors; residual signs following prior (inflight) redistribution of blood; statokinetic disorders and atrophy of muscles of the legs; anemic syndrome with subsequent decline in erythrocyte count (for the first few postflight days) followed by restoration thereof; change in fluid-electrolyte balance with a tendency toward fluid retention; diminished immunological resistance.

All of the above syndromes were less marked after the 140-day flight than after the one lasting 96 days. In the postflight period, rehabilitation and therapeutic

FOR OFFICIAL USE ONLY

measures were instituted to accelerate the readaptation process; they consisted chiefly of regulated motor activity, rehabilitation massage of muscles, therapeutic physical culture and hydrotherapy. The rehabilitation and therapeutic measures were used in two stages after the 140-day flight, at the spaceport and in Kislovodsk.

The mission lasting 140 days demonstrated once more that it is possible to purposefully control health status in flight and prepare the body for earth's gravity.

FOR OFFICIAL USE ONLY

GRAVITY AND CEREBRAL CIRCULATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 6-7

[Article by Yu. Ye. Moskalenko]

[Text] Special mechanisms developed in the course of evolution which assure adequate delivery of blood to the brain, with due consideration of the effects of earth's gravity.

The mechanisms that provide for stability of the system of cerebral circulation are based on the specific biophysical structure of this system, which consists of close correlation between volume and pressure of fluids in the closed cavity of the skull (arterial blood, venous blood, spinal fluid). The overall volume of these fluids is constant, but there could be efflux of a certain amount of spinal fluid into the spinal cavity through an orifice of limited size. As a result, structural stability of the circulatory system of the brain is provided not only by the stability of its different elements, but composition of the system as a whole, as an integral structure.

The mechanisms involved in maintaining functional stability of the cerebral circulatory system are based on several circuits of regulation with their own feedback channels, based on different physiological principles (myogenic, metabolic and neurogenic). Coordinated activity thereof provides for constancy of overall cerebral blood flow with change in conditions of influx and efflux of blood from the skull under the influence of gravitation.

These two groups of mechanisms were formed at certain stages of evolution of the animal kingdom, and they are already observed in higher reptiles. As a result of the function of these mechanisms, the circulatory system of the brain can function well, not only in earth's gravity. As shown by the study of intracranial hemodynamics during exposure of an organism to transverse and longitudinal accelerations, the circulatory system of the brain is capable of functioning in the presence of significant G forces. The range of endurance thereof is quite variable.

Functional stability of the cerebral circulatory system fluctuates over a wide range, depending on the condition of the organism. This property can change in the case of prolonged weightlessness, as well as pathological processes.

FOR OFFICIAL USE ONLY

OXYGENATION OF HUMAN TISSUES DURING SPACE FLIGHTS ABOARD THE SALYUT-6 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICESKOY BIOLOGII I AVIAKOSMICESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 7-10

[Article by Ye. A. Kovalenko, A. Vatsek, M. P. Bobrovnitskiy, N. V. Lapteva, V. A. Kaptsov, V. N. Sementsov, V. P. Pushkin, S. N. Kharin, V. K. Gabyshev, Kh, Khaaze and Z. Sarol']

[Text] Man's life and fitness for work depend on the constant access of oxygen into his body. However, until recently, there has been insufficient information about the overall, ultimate area of uptake of oxygen in tissues when he is exposed to space flight factors.

There is reason to assume that changes may occur in delivery of oxygen and oxidative processes in tissues during space flights and under the influence of weightlessness. It is known that, in weightlessness, there is redistribution of blood from the lower parts of the body to the upper ones. In weightlessness, there is more intensive exit of the liquid part of blood from capillaries into tissues, and one observes some softening [pastiness] of tissues. There may be changes in reflex influences on bioenergetic processes.

Of course, all this could affect oxygenation of peripheral tissues, including the skin.

Preliminary studies of oxygenation of the skin of man with simulation of the effects of weightlessness by means of hypokinesia, immersion, as well as anti-orthostatic [head down] body position, clearly showed that, indeed, under these conditions there are changes in  $PO_2$  level and nature of  $O_2$  uptake in the human skin.

A study of oxygenation of the skin during the space mission of the first international crew aboard the Salyut-6 orbital station was conducted for the first time within the framework of the "Intercosmos" program by scientists of the USSR and CSSR, on the basis of the above assumptions and facts obtained under ground-based conditions.

Subsequently, analogous studies were conducted by scientists of the USSR, CSSR, Polish People's Republic and GDR during the missions of the second and third international crews. The studies were conducted using the onboard Oxymeter instrument,

FOR OFFICIAL USE ONLY

[illegible]

These data are not only of theoretical significance for disclosure of the mechanisms of effects of weightlessness on transport and utilization of  $O_2$  by the body, but can be useful in expanding and deepening medical monitoring, and developing new preventive measures to be used during and after space flights.

FOR OFFICIAL USE ONLY

REGULATION OF REGIONAL HEMODYNAMICS DURING LONG-TERM SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 10-11

[Article by Kh. Kh. Yarullin and T. D. Vasil'yeva]

[Text] Bipolar rheography was used to study circulation in the brain, lungs, liver, fingers and lower legs under basal metabolic conditions and with postural loads, before and after the 96-day flight of the crew of the first mission aboard Salyut-6. REG [rheoencephalograms] of the hemispheres were studied during the flight using a tetrapolar rheograph.

The increase in pulsed filling of the cosmonauts' hemispheres, which was observed during the flight, did not exceed 94% of the base value. In our opinion, this is indicative of adequate compensation of intracranial plethora and venous stasis. The latter was manifested by marked venous waves on the REG, indicative of difficult and slow efflux of blood from the cranial cavity, and this was confirmed by their disappearance under the influence of LBNP [lower body negative pressure]. Throughout the flight, the commander presented prevalence of signs of active dilatation of cerebral vessels, mainly arterial ones, while in the flight engineer there were signs of plethora of intracranial veins.

The signs of intracranial venous plethora were compensated by two mechanisms: in some cases there was predominant constriction of precapillary vessels and in the others dilatation of cerebral arteries (particularly collaterals).

On the first postflight day, both cosmonauts presented marked interhemispheric asymmetry of pulsed delivery of blood to the brain. The significant asymmetry of filling of the hemispheres disappeared on the 3d postflight day. Already on the first day after termination of the flight, venous waves disappeared on the REG of both cosmonauts, i.e., signs of venous stasis in the brain. They appeared only in one of the cosmonauts during the antiorthostatic test [head down], in spite of obvious improvement of endurance thereof after the flight. In both cosmonauts, this improvement was manifested by significantly less marked increase in pulsed delivery of blood to the brain, against the background of compensatory increase in tonus of cerebral vessels, especially arterioles and small arteries. These manifestations of the sequelae of adaptation of the vascular system of the brain to weightlessness were the most marked in the first week and leveled off by the 30th postflight day.



FOR OFFICIAL USE ONLY

Endurance of the orthostatic test was significantly diminished in both cosmonauts on the first postflight day: there were signs of marked arteriolar hypotension, which were more marked in the vertebrobasilar system.

On the first postflight day, both cosmonauts presented increased pulsed delivery of blood to the lungs, with concurrent increase in tonus of arteries with a large caliber. These signs of compensatory vascular hypertension in the lungs leveled off on the 12th day, while the signs of vascular hypotension in the lower leg disappeared on the 7th day of the recovery period.

There was rather rapid restoration of hemodynamic parameters, which was indicative of the functional nature of the changes and their reversibility. On the 30th day of the rehabilitation period, the parameters of pulsed filling, tonus and elasticity of vessels were close to their preflight values in virtually all of the regions studied.

FOR OFFICIAL USE ONLY

RESULTS OF ELECTROCARDIOGRAPHIC EXAMINATION OF COSMONAUTS DURING FLIGHT ABOARD  
THE SALYUT-4 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 11-12

[Article by V. R. Lyamin, O. G. Itsekhovskiy, A. P. Polyakova, I. A. Yevdokimova,  
L. I. Voronin, V. N. Sidorov and Z. A. Golubchikova]

[Text] A functional test was used, with graded physical load, on a bicycle ergo-  
meter, on the 14th, 22d and 37th flight days for the commander, on the 22d and 37th  
days for the flight engineer, in order to examine adaptability of the circulatory  
system in weightlessness and predict the condition of the cosmonauts during the  
63-day flight of the second mission aboard the Salyut-4 station. The functional  
test was used for 5 min at a pedaling rate of an average of 440 kg-m/min. We  
analyzed EKG data before and after pedaling, as compared to analogous tests con-  
ducted before the flight and in postflight studies.

In all of the tests with graded exercise, the cosmonauts presented a sinus rhythm  
with insignificant respiratory arrhythmia. In all of the tests, the increment  
of heart rate after the test was greater for the commander than the flight  
engineer.

Duration of electrical systole (QT) corresponded to the dynamics of their heart  
rate in both cosmonauts.

Atrioventricular conduction (PQ) increased by 0.02-0.03 s in the recovery period  
on the 14th and 22d days of flight, as well as 3 days after it, in the commander,  
whereas no definite direction of changes during the flight was demonstrable in  
the flight engineer.

The changes in duration of intraventricular conduction (QRS) were within the  
range of fluctuations in the preflight period in both cosmonauts.

There was a decline of amplitude of T waves, as compared to preflight and post-  
flight findings. This decline persisted on the first postflight day in the  
flight engineer.

After the test, the configuration, direction and amplitude of P, Q, R and S  
waves did not change appreciably, whereas the amplitude of T waves had a tendency  
toward further decline. The cosmonauts did not notice any unpleasant sensations  
referable to the heart.

**FOR OFFICIAL USE ONLY**

The changes in time-related amplitude parameters of the EKG were within the range of normal fluctuations, while the decline in amplitude of the T wave demonstrated in both cosmonauts could apparently be attributed to changes in anatomical position of the heart in the chest, as well as some changes in metabolic processes of an adaptive nature.

Analysis of the findings according to results of electrocardiographic studies of cosmonauts before and after pedaling on the bicycle ergometer before, during and after the flight failed to demonstrate any pathological deviations in the cardiovascular system.

FOR OFFICIAL USE ONLY

STUDY OF HEMODYNAMIC EFFECTS OF WEIGHTLESSNESS IN GROUND-BASED MODEL EXPERIMENTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 13-14

[Article by Ye. I. Vorob'yev, V. I. Lobachik, A. A. Savilov, S. V. Abrosimov and V. V. Zhidkov]

[Text] The experience gained by Soviet and American researchers has shown that redistribution of blood caused by weightlessness is one of the chief causes in functional changes in the circulatory system. However, to date we have only general information about the nature and extent of hemodynamic changes under such conditions, while the actual process of redistribution of blood has been virtually unstudied. The latter is related, to a significant extent, to the limited capabilities of onboard research equipment.

With increase in duration of space missions, the urgency of problems of the effects of weightlessness on hemodynamics is increasing substantially, particularly in view of the need for more active correction of cardiovascular function at different stages of flight. In this regard, it is growing obvious that it is imperative to conduct basic research for in-depth investigation of this problem with the use of model experiments.

For this purpose, a series of experimental studies was conducted, in which anti-orthostatic [head down] hypokinesia served as a hemodynamic model of weightlessness.

Mainly the radioisotope tracer method was used to solve the proposed problems; it permits not only determination of the direction of hemodynamic changes, but reliable quantitative evaluation thereof. In addition, clinicophysiological methods were used, such as measurement of arterial blood pressure, pulse tachometry, electrocardiography, etc. Ultrasonic echocardiography was also used to assess intracardiac circulation and myocardial contractility.

Quantitative and qualitative characteristics of distribution of blood as related to different angles of inclination of the human body were obtained in this study. Blood shifted to the upper half of the body in antiorthostatic position, mainly due to efflux from the lower extremities. The quantitative changes increased with increase in angle of body inclination.

Under conditions of antiorthostatic hypokinesia, the same direction of this redistribution of blood was retained, and only quantitative findings changed.

FOR OFFICIAL USE ONLY

It was also noted that the degree and nature of redistribution of blood during use of negative pressure and the orthostatic test depended appreciably on both the initial endurance of the subjects of these functional tests and degree of deconditioning of their cardiovascular system during hypokinesia. Analysis and comparison were made of traditional rating criteria of endurance of these tests (pulse, arterial pressure, etc.) to indicators of redistribution of blood in the body.

In conclusion, there was discussion of the findings and prospects for future use of the radiotracer method for problems of space physiology.

FOR OFFICIAL USE ONLY

ANALYSIS OF CHANGES IN DIASTOLIC PHASES OF THE RIGHT AND LEFT VENTRICLES DURING  
140-DAY SPACE FLIGHT OF COSMONAUTS ABOARD AN ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 14-15

[Article by S. I. Ponomarev and I. V. Alferova]

[Text] In view of the fact that the contractile function of the heart in systole depends significantly on presystolic distension of the myocardium in accordance with the Frank-Starling mechanism ("length-contraction"), it is deemed important to study the phasic structure, not only of the systole, but diastole.

During the second mission aboard the Salyut-6 orbital station, studies were made of phasic structure of the cardiac diastole according to kinetocardiographic (KKG) data. The KKG curves were recorded with Polynome equipment at relative rest. Determination was made of the duration of phases of the left and right ventricles: phase of isometric contraction (C), ejection period (E), phase of isometric relaxation (IR), period of filling (PF) including rapid (RF) and slow (SF) filling and atrial systole (AS).

The observed changes in phasic structure of the ventricular systole during flight were characterized by dynamic phasic syndromes, with prevalence of signs of the syndrome of volume load for the left ventricle and some signs of the hypodynamia syndrome for the right ventricle. In the phasic structure of the diastole, we observed shortening of the IR phase (with the exception of longer IR of the right ventricle in one of the cosmonauts), with initial increase in other diastolic phases (RF was increased over virtually the entire flight, with the exception of RF for the left ventricle in the same cosmonaut). Starting on the 41st flight day, some parameters of diastolic phases diminished, as compared to mean preflight data. In the postflight period, the parameters of the systole and diastole reverted to the initial levels.

These changes can be interpreted on the basis of the adaptation conception, which includes both immediate adaptive reactions and long-term adaptive reactions.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

TEMPERATURE REGULATION IN WEIGHTLESSNESS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 15-16

[Article by Yu. A. Rostopshin]

[Text] The problem of providing the best microclimate for the human body during space flights is not limited to solving purely technical problems. Validation of the characteristics of a system for control of the microclimate requires consideration of the functional distinctions of physiological systems of the body in weightlessness.

According to conceptions that have been formed, which are based on calorimetric studies of heat production by man in small and confined places in weightlessness and on earth, human thermoregulation is little-affected by weightlessness. However, the experience of manned space flights and scientific research aboard biosatellites cause us to suspect that things are not so simple with temperature regulation in weightlessness. The existing information indicates that a new temperature mode, characterized by a drop in body temperature, is established in weightlessness. A mathematical model of physiological thermoregulation, which takes into consideration the link between temperature-dependent processes of heat production and functional level of body organs and tissues, is proposed for interpretation of this phenomenon. This model describes the main processes involved in the body's utilization of energy to assure functional requirements. In this interpretation, weightlessness is simulated as a decrease in load function of a compartment of the model, which describes metabolic heat production in muscle tissues, which corresponds to the actually observed unloading of muscle tissues of the skeletomuscular system.

Examination of versions of the model revealed that a decline in functional level or load function in the muscular compartment of the model brings the system into a different temperature mode, to temperatures that are lower in different parts of the body than initially. Since temperature regulation is effected in accordance with the principle of minimum expenditure of energy, while the position of this minimum on the temperature scale is determined by the temperature-related distinctions in activity of enzymatic systems, the change to a new temperature mode occurs at the rate of temperature adaptation of enzymes and is associated with increased expenditure of energy by the system. It is found that a load on the system, caused by a change to a new temperature mode, could be partially compensated by appropriate correction of ambient temperature. Correlations were obtained that link the temperature mode of the body with the functional level of its subsystems. These correlations can be used to validate requirements for microclimate parameters.

FOR OFFICIAL USE ONLY

EVALUATION, PREDICTION AND OPTIMIZATION OF COSMONAUTS' EFFICIENCY DURING FLIGHT  
ABOARD THE SALYUT-6 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 16-17

[Article by V. I. Myasnikov, K. K. Ioseliani and G. V. Izosimov]

[Text] The efficiency [fitness for work] of cosmonauts was assessed on the basis  
of the reports of crew members, number and nature of inquiries while performing  
work operations during communication sessions, parameters obtained over telemetry  
channels. The psychosomatic condition of crew members was also taken into con-  
sideration.

The study of efficiency in the course of a 140-day flight revealed that the level  
and effectiveness of work performance of cosmonauts V. Kovalenko and A. Ivanchenkov  
were high throughout the flight. This was indicated by the large volume and high  
quality of work related to extravehicular activity, docking and unloading of  
Progress-2, 3 and 4 cargo craft, meetings and joint work with international crews  
from Soyuz-30 and 31 spacecraft, technological experiments, "Splav" [allow] and  
"Kristall" [crystal], taking photographs and observations of earth's surface and  
stars, as well as a number of other studies.

A large number of studies conducted at their own initiative, in the interests of  
the national economy and updating the interior of the station, was a typical  
feature in the performance of the cosmonauts.

During the flight period the psychosomatic condition of crew members was rather  
good. The sleep disturbances, which were observed in the commander at the end  
of the second month of flight and sporadically manifested emotional stress had  
little effect on the nature of performance.

Prediction of efficiency was made on the basis of comparison of actual fitness to  
data from model experiemnts obtained in the course of training, comments of the  
crew, degree of interest of the cosmonauts in performing a current flight assign-  
ment. Prompt adjustment of work schedules and plans played a substantial role  
in preserving efficiency.

Special attention was devoted to psychological support, which included optimum  
planning of work, work and rest schedule. The optimum effect of psychological  
support was more distinct when the individual traits of cosmonauts and their sets



**FOR OFFICIAL USE ONLY**

on various types of work were taken into consideration. Highly qualified specialists in different fields (meteorologist, oceanologist, geologist, specialist in forestry and others) were called upon as consultants in order to create high motivation.

The aggregate of optimizing measures made it possible to retain efficiency and great interest in the studies in the crew members to the end of their mission.

FOR OFFICIAL USE ONLY

EFFECT OF 140-DAY SPACE FLIGHT ON MOTOR SYSTEM AND SYSTEM OF REGULATION OF MOTOR FUNCTIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 18-19

[Article by I. B. Kozlovskaya, O. P. Kozerenko, Yu. V. Kreydich and A. S. Rakhmanov]

[Text] We know that there are disturbances of complex coordinated motor acts, decline of muscle tone and force of muscular contractions, and muscular atrophy in man under the influence of weightlessness (V. S. Gurfinkel' et al., 1973; N. N. Gurovskiy et al., 1975, and others). Our objective here was to evaluate the changes in the motor system of cosmonauts who had participated in a 14-day flight.

We examined the following: main proprioceptive inputs of the skeletal system according to thresholds of vibration sensitivity and muscles according to thresholds and function of involvement of tendon reflexes; the spinal system and, in particular, interlimb synergism; muscles, according to coefficient of electromyographic efficiency of muscular contraction; systems of movement control according to cyclography of locomotor acts, stabilography and use of methods for studying postural synergism. These studies were performed before, and on the 2d, 5th, 9th, 26th and 42d postflight days.

As a result of these studies, it was established that there were substantial changes in the spinal system, manifested by increased sensitivity to muscular afferent input and impairment of interlimb reflex interactions, which leveled off significantly by the 5th day. There was an increase in electromyographic "cost" of muscular exertion and reduction of maximum level of the reflex response; the most profound disturbances were demonstrated in activity of the systems of postural regulation, which persisted even on the 26th day.

Both cosmonauts presented impairment of function of mechanisms for maintaining a vertical position. Tremor at a frequency of 7-9 Hz, which was particularly marked when the eyes were closed and in load-bearing positions, was recorded on the EMG of crural muscles (and the stabilogram) while holding this position; the amplitude of the EMG was twice as high in erect position than before the flight.

Postural synergism, which provides for stability of vertical position with changes in position of the body and with sudden perturbations (graded jarring in the sagittal plane), was substantially impaired. The thresholds of electromyographic responses to perturbation were low (under 4 kg, versus 6 kg before the flight); their

FOR OFFICIAL USE ONLY

**FOR OFFICIAL USE ONLY**

amplitude and duration more than doubled; flexor and extensor muscles of the ankle joint functioned synchronously. Before the flight, such a response was observed only with very strong perturbations. With voluntary deflection of the body, the postural changes were made with a great lag (400-500 ms, versus 200-250 ms before the flight) and duration thereof increased to 3-6 s, with distinct change in coordinational structure. The dynamics of restoration of postural synergism presented all of the elements of learning.

The intensity and duration of disturbances referable to peripheral muscles, proprioceptive inputs, spinal reflex mechanisms and systems of postural regulation were not interrelated, which warrants the assumption that their origins are independent of one another, and that there are differences in mechanisms of their development.

FOR OFFICIAL USE ONLY

MICROFLORA IN THE CREWS OF SPACE STATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 19-20

[Article by V. M. Shilov, M. P. Bragina, O. K. Borisova, S. K. Kanareykina and T. Yu. Norkina]

[Text] In view of the future increase in duration of space flights, it is particularly important to study the microflora of the organism, since under such conditions there is an increased probability of infectious diseases in cosmonauts, the source of which could be representatives of man's conditionally pathogenic microflora.

In this work, we submit the results of studies of automicroflora of the crews of Salyut-4 and Salyut-6 space stations, before and after space flights.

The results of microbiological studies on the crew involved in the second mission aboard the Salyut-4 space station revealed that, in the course of the 63-day space flight, there was transmission of pathogenic staphylococcus, phagotype ZA/ZS [or 3A/3C or 3/S] from the commander to the flight engineer. However, we did not observe adaptation of staphylococci received as a result of mutual exchange.

In the course of the long-term space flight (140 days), the crew of the second mission aboard the Salyut-6 space station showed exchange of pathogenic staphylococci between the cosmonauts. On the one hand, there was transmission of pathogenic staphylococci, phagotype ZS/55 from the flight engineer to the commander. On the other hand, there was transmission of highly toxigenic and pathogenic staphylococci, phagotype 53/83A from the commander of Soyuz-31 (during the visit of the latter) to the flight engineer aboard Salyut-6. However, in this case too, no adaptation was demonstrable with regard to the pathogenic staphylococci received as a result of exchange.

The obtained data are indicative of a high degree of contact, in the sense of infection, in pressurized cabins, and they could be of some epidemiological significance in the case of long-term space flights.

A study of the biological properties of Escherichia isolated from the crew on the second expedition aboard the Salyut-4 space station revealed a decline in antagonistic activity of E. coli determined by extrachromosomal genetic elements--colicinogenic factors. In view of the fact that colicinogenicity is one of the

**FOR OFFICIAL USE ONLY**

forms of microbial antagonism, the observed decrease in number of colicinogenic cultures of E. coli could be interpreted as weakening of the defense reaction of the normal microbial cenosis.

There is discussion here of the practical implications of the obtained data for validation and development of measures directed at disease prevention among the crews of long-term space flights.

FOR OFFICIAL USE ONLY

MICROFLORA OF THE UPPER RESPIRATORY TRACT OF CREWS ENGAGED IN LONG-TERM SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 20-22

[Article by K. V. Zarubina]

[Text] With the increase in duration of space flights, there is an increased danger of onset of diseases among crew members. The possible pathogens could be representatives of the automicroflora, including microorganisms that populate the mucous membrane of the upper respiratory tract. We refer, first of all, to *Staphylococcus aureus*,  $\beta$ -hemolytic *Streptococcus*, bacteria of the genus *Klebsiella*, *Escherichia coli*, *Proteus mirabilis* and a few others. It is imperative to make a detailed study of the changes in composition of human autoflora in order to settle the question of choice of measures to prevent diseases during long-term exposure to space flight factors.

For this purpose, we made a comparative analysis of the microflora of the upper respiratory tract of the crews aboard two Salyut orbital stations. The species composition of autoflora of the crew of one of these stations was represented by nonpathogenic microorganisms inherent in these segments of mucosa before the flight. The levels of microorganisms in the nose, mouth and throat did not exceed those established for healthy people. After the flight, no increase in total number of microorganisms or changes in species composition of microflora, as compared to preflight findings, were demonstrated.

In contrast, the microflora of the crew engaged in one of the missions aboard the other orbital station presented some distinctions. Thus, we periodically found *E. coli* in small amounts, in the nose of one cosmonaut. The microflora of the upper respiratory tract of the other crew member was notable for diversity: pathogenic staphylococci were consistently demonstrated in the nose, while enterococci and representatives of the Enterobacteriaceae family (*Escherichia coli*, *Citrobacter*) were periodically found in the mouth and throat.

The long-term space flight was characterized by adverse changes in composition of autoflora of both cosmonauts. Already on the 37th flight day, there was a drastic enlargement of a microbial focus formed by *E. coli* in the nose of the first cosmonaut. There was almost a  $10^4$ -fold increase in number of *E. coli*, which constituted 97% of all microorganisms.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Significant quantities of *Proteus mirabilis* and repeated appearance of pathogenic staphylococci were observed in the nasal cavity of the second cosmonaut. Unusual (for this site) bacteria were found in the nose of both cosmonauts-- $\alpha$ -hemolytic and nonhemolytic streptococci. All of the above changes in species composition can be interpreted as signs of dysbacteriosis. As we know, the prolonged exposure to space flight conditions lowers immunobiological reactivity of the body. Evidently, as a result of this, marked changes in composition of microflora were also observed during the period of readaptation to ordinary living conditions. Expressly during this period they showed appearance of such microorganisms as  $\beta$ -hemolytic streptococci, pneumococci, bacteria of the species *Enterobacter aerogenes*, repeated appearance of pathogenic staphylococci and *Proteus mirabilis*. It is only by the 30th postflight day that the quantitative parameters and species composition of autoflora showed virtually no difference from the background findings.

Thus, prolonged space flights are not necessarily associated with changes in composition of microflora in crew members.

The severity of changes in composition of microflora of individuals spending time in a spacecraft cabin is, as shown by our findings, largely related to the initial state of automicroflora prior to the flights, in particular, apparently it is related to presence among autoflora of microorganisms that are not inherent in a given part of the integument.

This circumstance must be taken into consideration in medical evaluation of the microbiological status of crew members and to settle the question of necessity of measures to normalize the species composition of microflora.

FOR OFFICIAL USE ONLY

DISTINCTIONS OF INTESTINAL DYSBACTERIOSIS IN COSMONAUTS INVOLVED IN SPACE FLIGHTS OF DIFFERENT DURATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 22-24

[Article by N. I. Liz'ko, V. M. Shilov and G. D. Syrykh]

[Text] It is known that marked changes are observed in intestinal microecology under the influence of extreme factors, and that impairment of composition of intestinal microflora could have an adverse effect on the health and efficiency of cosmonauts during space flights (V. M. Shilov, N. N. Liz'ko, 1974; M. B. Bengson, 1970; R. M. Brockeffctal, 1974; C. R. Taylor, S. N. Zaloguyev, 1976). Already during the brief flights aboard the Soyuz-12, 13, 16, 19, 25, 28, 30 and 31 spacecraft we recorded changes in intestinal microbiocenosis of cosmonauts, which were characterized by a decrease in number of bifidobacteria and lactobacilli, to the extent of total disappearance, and increase in number of conditionally pathogenic enterobacteria. For this reason, it was considered important to demonstrate the distinctive features of dysbiotic changes in the intestine of cosmonauts with increase in duration of space flights.

A study of the microbial cenosis of the intestine of cosmonauts who participated in missions differing in duration aboard the Salyut-4 and Salyut-6 orbital stations revealed that the nature of changes in composition of intestinal microflora is analogous to the changes in intestinal microecology during short-term flights. However, unlike the latter, the changes in intestinal microflora were characterized by stability and more marked disturbances of microbial cenosis of the intestine of cosmonauts involved in long-term space missions. Thus, in the second crew member of the first mission aboard the Salyut-4 orbital station, the lactobacillus content did not reach the base level, even 1 month after the mission, while both cosmonauts involved in the 96-day flight presented significant disturbances in composition of intestinal microflora with development of proteus-related dysbacteriosis.

In view of the susceptibility of bifidobacteria to changes under extreme conditions, as well as their important role in vital functions of the organism and significance of the anaerobic component to preservation of stability of the intestinal microbial cenosis, we tried to use the product, Bifidumbacterin, for prophylaxis and normalization of intestinal microflora.

Use of this agent in ground-based experiments yielded a positive result, which enabled us to recommend it for preflight treatment of cosmonauts.



FOR OFFICIAL USE ONLY

Our findings were indicative of the beneficial effect of this agent on the aerobic flora of the cosmonauts' intestine. At the same time, against the background of intake of this agent, there were none of the changes in microbiocenosis inherent to the prelift-off period (in the second member of the crew of Soyuz-31). In contrast, no bifidobacteria were demonstrable in the first cosmonaut, who did not take this product, when tested on launching day, and there was a decline in lactobacillus content. Analogous differences were demonstrated between these cosmonauts in the postflight examination.

Intake of the above agent was recommended to cosmonauts involved in the second mission aboard the Salyut-6 orbital station, prior to starting on the 140-day flight. The obtained data warrant the belief that preflight treatment had a beneficial effect on the aerobic intestinal flora of both cosmonauts.

The results of these studies are indicative of the benefit of using Bifidumbacterin for prevention and normalization of disturbances of the intestinal microbiocenosis in cosmonauts under space flight conditions.

FOR OFFICIAL USE ONLY

CONDITIONALLY PATHOGENIC ENTEROBACTERIA AS POSSIBLE PATHOGENS OF VARIOUS INFECTIOUS PROCESSES IN SPACECRAFT CREWS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 24-25

[Article by N. A. Polikarpov]

[Text] At the present time, conditionally pathogenic enterobacteria are found to play an increased role in various infectious processes in man. The distinction of these pathogens is that they are highly resistant to antibacterial and disinfectant agents. It was demonstrated that infections caused by conditionally pathogenic microorganisms most often develop as a result of weakening of immunobiological resources. In view of the fact that the factors inherent in space flight may lead to weakening of defenses of the body and increased susceptibility to pathogens of infections, including representatives of automicroflora, it became necessary to study the quantitative and species composition of conditionally pathogenic enterobacteria in man, both in ground-based experiments and during actual space flights. A study was undertaken of the intestinal microflora of 100 clinically healthy subjects and 40 patients with various intestinal dysfunctions, in order to interpret the obtained data and set standards for conditionally pathogenic enterobacteria.

The studies revealed that conditionally pathogenic enterobacteria are widespread in both clinically healthy people and those with dysfunctions of the gastrointestinal tract. In clinically health people, the following bacteria were demonstrated the most often: *Kl. pneumoniae* in 45%, *Citrobacter* in 44%, *Ent. aerogenes* in 17% and *Ent. cloacae* in 11% of the cases. Bacteria of the genera *Proteus*, *Providencia*, *Ent. liquefaciens* and *Ps. aeruginosa* were found in isolated cases. Examination of people with dysfunctions of the gastrointestinal tract revealed an insignificant increase in incidence of bacteria referable to *Kl. pneumoniae* in 62.5% of the cases, *Ent. aerogenes* in 20%, *Citrobacter* in 50% and *Pr. vulgaris* in 2.5%, while such bacteria as *Pr. mirabilis* and *Ps. aeruginosa* were encountered 5 and 7.5 times more often. It was determined that conditionally pathogenic bacteria were present in most clinically healthy people (72.3% of those examined) in amounts of  $1 \cdot 10^3$  -  $1 \cdot 10^4$  bacteria per gram intestinal contents; in 17.7% there were  $1 \cdot 10^5$  and in 10% --  $1 \cdot 10^6$ ; in the presence of dysfunctions of the gastrointestinal tract, most conditionally pathogenic bacteria were demonstrable in amounts of  $1 \cdot 10^5$  -  $1 \cdot 10^8$  bacteria (in 71% of those examined). It was demonstrated that such conditionally pathogenic enterobacteria as *Kl. pneumoniae*, *Citrobacter*, *Ent. aerogenes* and *Ent. cloacae*

FOR OFFICIAL USE ONLY

may be present in clinically healthy individuals in amounts of  $1 \cdot 10^2$  to  $1 \cdot 10^6$  bacteria without clinical manifestations. However, when bacterial content of the intestine increases to  $1 \cdot 10^7$ - $1 \cdot 10^8$ , dysfunctions of the gastrointestinal tract were observed. The obtained data give us grounds to consider the norm to be both absence of conditionally pathogenic enterobacteria in the human intestine, or presence thereof in quantities not exceeding  $1 \cdot 10^6$  bacteria per gram intestinal contents. The studies revealed that subjects submitted to more difficult living conditions in pressurized chambers, as well as long-term hypokinesia, presented a significant increase in number of conditionally pathogenic enterobacteria, and in a number of cases this was associated with intestinal dysfunctions.

Analogous, but less marked changes were found in a study of microflora of the intestine of spacecraft crews, with regard to conditionally pathogenic enterobacteria.

FOR OFFICIAL USE ONLY

STUDY OF ANTIVIRAL IMMUNITY OF THE CREW OF THE SALYUT-6 SPACE STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZNNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 26-27

[Article by L. L. Fadeyeva, E. V. Khaletskaya, O. V. Nikolayeva, A. Yu. Selezneva and S. I. Pal'mina]

[Text] Studies were made of the distinctions of antiviral immunity: titer of antiviral antibodies and blood serum interferon level in cosmonauts; tests were also made for isolation of viruses.

In this study, the following were used: blood serum, washings and smears from the throat and nasal mucosa, urine, feces collected from cosmonauts at different stages of a space mission (before flight) and on the first day after landing. Blood serum was tested for antiviral antibodies with 12 viral antigens (measles, influenza A and B, types 1, 2 and 3 parainfluenza, types 1, 2 and 3 enteroviruses-polioviruses, adenoviruses and smallpox) in such serological reactions as the neutralization reaction (NR), complement fixation reaction (CFR) and agglutination inhibition (RAI).

No major deviations were demonstrated in blood serum samples taken before and after the mission. In essence, the titers of antiviral antibodies stayed at one level, or else fluctuated within the range of one dilution, showing a tendency toward decline. We observed high titers of antibodies to influenza A and B viruses, which was related to intensive circulation of these viruses at that period. Analogous titers were observed in the cosmonauts' blood serum of antibodies to type 2 parainfluenza virus and adenoviruses. With regard to other viral antigens (measles, smallpox, enteroviruses), the titers of antiviral antibodies remained at the same level before and after the space mission.

Interferon level was determined in samples of blood serum, smears and washings from the mucosa of the throat and nose, and urine. The conventional method of assaying interferon in human body fluids was used to treat blood serum and washings, for dialysis of urine and subsequent titration. Interferon was titrated according to depression of cytopathic action of a test virus (Indiana strain of vesicular stomatitis virus) on HEF [human embryonic fibroblast] culture. The reciprocal of maximum dilution inducing a delay in cytopathic action in 50% of the cultures (in  $IU_{50}/m\ell$  [IU--immunizing unit]) was taken as the interferon titer. In all of the blood serum samples we tested, interferon titers did not exceed 128  $IU_{50}/m\ell$ , but most often were in the range of 16-23  $IU_{50}/m\ell$ . No interferon was demonstrable in either the throat or nasal mucosa, or in urine.

**FOR OFFICIAL USE ONLY**

Virus was isolated from samples of throat and nose washings in 10-day chick embryos, as well as HEIA, HEP, KH cell tissue cultures, chick embryo fibroblasts and primary cells of HEF. Virus from samples of feces was isolated on suckling mice. Samples of washings and smears of the nasal and throat mucosa in cell culture underwent 4 passages each, and in 10-day chick embryos and suckling mice 2-3 passages. Virus was not isolated in any instance.

FOR OFFICIAL USE ONLY

BIOLOGICAL PROPERTIES OF LACTOBACILLI ISOLATED FROM COSMONAUTS BEFORE AND AFTER SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA, VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 27-28

[Article by A. A. Lentsner, Kh. P. Lentsner, M. E. Mikel'saar, M. E. Tyuri, M. A. Toom and M. E. Vyal'yaots]

[Text] Changes have been described, in the course of experiments in chambers and spacecraft mockups, in biology of such representatives of the human microflora as Staphylococcus aureus, Escherichia coli and Clostridium perfringens. In particular, a decline was found in antagonistic activity of E. coli (V. M. Shilov, 1975). However, there are no data in the literature concerning studies of biology of lactobacilli in the course of space flights. Yet these microorganisms play a rather substantial role in protective properties of the human microflora.

In this report, we submit the results of studies of physiological, biochemical and antagonistic properties, lysozyme activity and sensitivity to antibiotics of lactobacilli isolated from the saliva and feces of five cosmonauts before and after completing three space experiments: 8-day flight aboard the Soyuz-13 spacecraft, 30- and 63-day flights aboard the Salyut-4 orbital station. In all, 593 strains of lactobacilli were studied, 199 from saliva and 394 from feces.

Physiological and biochemical properties were studied by means of 16 tests; antagonistic properties were determined in relation to E. coli, Newcastle's dysentery bacillus, staphylococcus and streptococcus; lysozyme activity was demonstrated by the method of agar plates on solid nutrient medium containing an autoclaved suspension of micrococcus; paper disks with 19 agents were used to test sensitivity to antibiotics.

As shown by the findings, the conditions involved, even in the 63-day flight aboard Salyut-4 did not elicit any particular changes in biological properties of lactobacilli. In particular, there was essentially no change in antagonistic activity of lactobacilli, their sensitivity to antibiotics and capacity of Lactobacillus fermentum to produce lysozyme. Thus, the biological properties of lactobacilli, at least within the range of the traits studied, remained stable in the digestive tract of participants in three space flights varying in duration.

FOR OFFICIAL USE ONLY

HORMONAL STATUS OF COSMONAUTS AFTER FLIGHT ABOARD THE SALYUT-6 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 28-29

[Article by R. A. Tigranyan, N. F. Kalita, E. A. Pavlova, V. M. Ivanov and B. V. Afonin]

[Text] The state of the cosmonauts' endocrine system was evaluated according to levels of several hormonal compounds in blood and urine assayed before and after the flight.

We assayed levels of the following in blood: insulin, thyrotropic hormone (TTH), thyroxine ( $T_4$ ), triiodothyronine ( $T_3$ ), testosterone, aldosterone, cyclic AMP (cAMP), prostaglandins (PG) A + E,  $F_1$ - $\alpha$ ,  $F_2$ - $\alpha$ , plasma renin activity, and we determined the coefficient of effective thyroxine (CET) and thyroxine-binding capacity of globulins (TBG). In addition, we assayed excretion in urine of total 17-hydroxy-corticosteroids (17-HCC) and fractions thereof (free, glucuronides, sulfates), 17-ketosteroids (17-KS) and aldosterone. The radioimmune method was used to assay levels of hormonal and biologically active compounds in blood and aldosterone in urine; total 17-HCC and fractions thereof were assayed in the reaction with phenylhydrazine and 17-KS in the reaction with metadinitrobenzene.

A comparison of the results of preflight and postflight tests revealed several changes, the most important of which are as follows.

The insulin level, which was above normal before the flight in Yu. V. Romanenko, rose significantly on the 1st and 7th postflight days in both cosmonauts, exceeding the normal range; however, it normalized by the 32d day. In both cosmonauts, there was an appreciable drop of blood testosterone level 1 day after landing, and it was close to the preflight value on the 7th day of the postflight period. It must be noted that plasma renin activity exceeded normal levels in both cosmonauts in the preflight period, then dropped appreciably right after landing; aldosterone excretion in urine increased appreciably in both cosmonauts, as compared to the preflight level. The dynamics of changes in parameters characterizing functional activity of the thyroid (TTH,  $T_3$ ,  $T_4$ , CET and TBG), as well as cAMP level in blood of both crew members, were in different directions, and they depended on the initial levels of these compounds before the flight. The PG pressor group ( $F_1$ - $\alpha$  and  $F_2$ - $\alpha$ ) levels in both cosmonauts demonstrated before the flight are of some interest: they exceeded the conventional norm, while the A + E PG were below normal levels at this time; in the readaptation period,

FOR OFFICIAL USE ONLY

the dynamics of changes in PG were in different directions in the two cosmonauts. The high level of excretion in urine of total 17-HCC, both before and after the space flight, starting on the first postlanding day, with concurrent increase in percentage of free 17-HCC and decrease of glucuronides in urine, which is indicative of prevalence of processes of 17-HCC secretion over inactivation thereof, showed that there was a marked state of stress in adrenocortical function. In the postflight period, there was decreased excretion of 17-KS in urine in both cosmonauts.

The obtained data indicate that the 96-day space flight was associated with some change in hormonal status of the cosmonauts, and it was the most marked on the first 7 days after the space mission, which is probably directed toward maintaining homeostasis during the period of readaptation to earth's gravity.



FOR OFFICIAL USE ONLY

BASIC PROBLEMS OF MAN'S ADAPTATION TO SPACE FLIGHT CONDITIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) p 30

[Article by A. V. Yeremin and N. Kh. Yeshanov]

[Text] Man's adaptation to space flight factors takes place in accordance with the theses of adaptation theory.

Weightlessness is the most difficult and least studied problem. In principle, the weightlessness factor is not new to man. As man moves, he can alter the magnitude and direction of gravity to which he is exposed over a wide range. For systems that provide for a vertical position, the horizontal position is virtually tantamount to weightlessness.

The absence of customary afferentation in weightlessness is not an effective deterrent to the stereotype reaction to a pseudovertical position. Following the biorhythm and being psychologically reinforced, the functional complex "works" on the vertical position which actually does not exist. This determines the severity of symptoms related to displacement of fluids during the first days of a space flight.

The adjustment made in the function of systems in the course of adaptation to weightlessness inevitably leads to undesirable changes, which can be predicted and prevented.

There are no units to measure the process and state of adaptation, so that evaluation of intensity and depth of adaptation can only be relative. According to these parameters, adaptation to weightlessness (taking into consideration the preventive measures in current use) is similar to adaptation to moderately high altitudes or the north.

With some degree of caution, it can be assumed that, in the absence of other obstacles that may be manifested during a long-term space flight, weightlessness is not an insurmountable barrier to development of cosmonautics.

FOR OFFICIAL USE ONLY

EFFECTS OF WEIGHTLESSNESS AND EARTH-BASED SIMULATION THEREOF ON HEMOGLOBIN SYNTHESIS IN MAN

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 31-32

[Article by I. S. Balakhovskiy, R. K. Kiselev and V. I. Legen'kov]

[Text] The metabolic changes observed following space flights are mostly nonspecific, moderate and not always consistent. Only some of them, in particular, reduction of hemoglobin mass, were demonstrated in all examined cosmonauts who had participated in flights lasting more than 2 weeks.

Using the carbon monoxide method, which was specially developed for this purpose, a study was made of hemoglobin mass of crew members who had participated in flights aboard Salyut-3, 4, 5 and 6 orbital stations of different duration, before and at different times after the flights. By the end of the flights, there was a decrease in hemoglobin mass, which was usually below 350 g/m<sup>2</sup>. Interestingly enough, a reduction in hemoglobin mass occurred only during the first 2 months of flight, after which the level stabilized and it was about the same, both after the 49- and 96-day flights, decreasing by about 25-35%, as compared to base values, and the decrease constituted 16% in both crew members after the 140-day flight.

The concentration of hemoglobin, erythrocyte count and hematocrit showed little change immediately after landing, as compared to preflight data, but they declined during the first 2 weeks, then gradually increased, returning to base values by the 45th-60th days. Reticulocyte content immediately after the flights was significantly lower than base values in most cases, it was also low during the flight, then increased and continued to remain several times higher than before the flight for a month or more.

It was possible to reproduce similar hemopoietic changes in man on earth, with the use of antiorthostatic hypokinesia. Model experiments enabled us to study the dynamics of hemoglobin concentration and reticulocyte count at the early stage of hypokinesia. For the first day of hypokinesia, peripheral blood hemoglobin concentration increased significantly, reaching 16-19g%. Concurrently, by the 3d-4th day, there was a distinct decrease in reticulocyte content of peripheral blood. The decrease in hemoglobin mass is the metabolic change that is the most specific to space flights demonstrable up to this time.

FOR OFFICIAL USE ONLY

AUDITORY FUNCTION OF MAN IN THE PRESENCE OF TRANSVERSE ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 32-33

[Article by V. Ye. Grishanov]

[Text] Experimental studies of piloting a flying vehicle by means of audio equipment in the presence of transverse accelerations revealed that it is feasible on a rather satisfactory level (A. S. Barer, A. S. Yeliseyev, V. Ye. Panfilov, S. A. Rodin, 1968).

The increased role of audio instruments [indicators], as one of the most important channels of information for the pilot, makes it necessary to study man's auditory function during exposure to various flight factors. This study was conducted in order to examine man's hearing sensitivity during exposure to transverse accelerations of 4 to 14 G.

The following parameters of hearing were tested: tonal thresholds of auditory sensitivity for air and bone conduction, differential thresholds of hearing for volume (VS) and pitch (PS) of sounds.

The results of these studies revealed that accelerations of 4 and 6 G have virtually no effect on threshold of auditory sensitivity for air conduction. Starting with 8 G, there is a reliable increase in tonal thresholds of sensitivity for air conduction, by 4-5 dB. Acceleration of 10 G increased the tonal thresholds by 8-9 dB, and with 12G the increase in tonal thresholds constituted a mean of 14-15 dB. Maximum decline of auditory sensitivity, which was noted with acceleration of 14 G, constituted a mean of 20 dB. At low frequencies, the decline was at a maximum, reaching 25 dB.

Testing of auditory sensitivity for bone conduction revealed that a reliable increase in tonal thresholds of hearing was recorded with accelerations of 12 and 14 G, constituting a mean of 7-10 dB. This increase was uniform over the entire tone scale.

As shown by the results of testing differential thresholds for VS, a reliable increase was observed only with acceleration of 8 G. Maximum increase of VS was noted at 14 G, and it constituted a mean of 2.5 dB for carrier frequency of 1000 Hz and 3.6 dB for 500 Hz. With regard to studies of the differential threshold for PS, it must be noted that a reliable increase of PS was noted only

FOR OFFICIAL USE ONLY

with acceleration of 10 G. At 15 G, the mean increase in PS constituted 3.8% with carrier frequency of 1000 Hz and 3.3% at 500 Hz.

Thus, on the basis of these studies, we can refer to deterioration of auditory sensitivity of man in the presence of high levels of transverse accelerations. Analysis of the experimental data warrants the belief that the demonstrated functional changes in the auditory analyzer occur as a result of combined damage to both the sound-conducting system of the ear and its sound-receiving part.

FOR OFFICIAL USE ONLY

STUDY OF DYNAMICS OF BLOOD AND LYMPH CIRCULATION IN MAN BY STIMULATION METHODS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 33-35

[Article by V. N. Krut'ko, I. V. Arsent'yeva and V. G. Shabel'nikov]

[Text] Simulating modeling is one of the effective means for analysis and prediction of man's state in extreme situations. One of the variants of the models of circulation that we developed enables us to simulate hemodynamic processes in a hemodynamic circuit, including components of arteries of systemic and pulmonary circulation, veins in the systemic circulation, right atrium, veins in the pulmonary circulation and left atrium. In this model, peripheral resistance and blood flow are divided into three parts: renal, muscular, "not renal, not muscular." This circuit is controlled by the unit for autonomous nervous regulation according to arterial pressure level,  $PO_2$  in tissues, effectiveness of delivery of blood to the central nervous system and intensity of exercise. The model has hydrodynamic circuits for regulation of cardiac output and vascular resistance. This model enables us to study effects on the functional state of the cardiovascular system such as, for example, the effects of increasing cardiac output in the presence of cardiac hypertrophy or decreasing myocardial hypoxia, increasing vascular resistance in the systemic circulation with increase in viscosity of blood or concentration of angiotensin (for arteries), the effect of varying the parameters of the cardiovascular system itself, and others.

We studied the reactions of the cardiovascular system to acute hypervolemia and permanent elevation of pressure in the right and left atria (a situation that exists in the antiorthostatic test). We found that the hydrodynamic circuit rapidly (with a time constant of less than 1 s) changes to a different stationary mode characterized by elevation of pressure and flow indicators. It is noteworthy that the circuit demonstrates its own intrinsic ability to maintain homeostasis (for example, a permanent elevation of atrial pressure by 40 mm Hg leads to such a compensatory hemodynamic change that pressure in the atria drops to  $8 \pm 10$  mm Hg), which does not require the involvement of neural circuits of regulation, the system of fluid-electrolyte metabolism, and others.

The model we have developed can operate either independently or in a complex with other models, which expands its capabilities substantially. For example, we used a combined hemorespiratory model to examine two opposing hypotheses concerning the mechanism of effects of changes in negative intrapleural pressure due to respiratory excursions on hemodynamic characteristics. According to the first

FOR OFFICIAL USE ONLY

hypothesis, intrapleural pressure has a suction effect mainly on veins passing in the chest and according to the second hypothesis, on the atria. A comparison of the modeling results to experimental data revealed that the first hypothesis, offers a good explanation of the effect of respiration on hemodynamics in the systemic circulation, whereas the second is acceptable for explanation of processes occurring in the pulmonary circulation.

The model of lymph circulation that we developed enables us to simulate processes of circulation of various components of blood (in particular, lymphoid elements and plasma) through body tissues and the lymphatic system. The lymphatic system is represented by an aggregate of chains of lymph nodes of different length and a spleen compartment. Lymph goes into each node from the preceding node, if there is one, from the segment of tissue drained by this lymph node and from blood vessels traveling to the node. In addition, there are sources of the circulating component in this model, in lymph nodes and the spleen, which enable us to include processes of reproduction and destruction of lymphocytes in the study.

In addition to processes of redistribution of components of the immune reaction under normal and extreme conditions, the model permits investigation of the dynamic effects of deposition of fluid and constituents of blood in the interstitial space and lymphatic system.

Thus, use of the model to study the concentration of recirculating lymphocytes in human blood as a function of rate of passage of lymphocytes through the compartments of tissue, lymph nodes and spleen revealed that, when the mean time of retention of lymphocytes in these compartments is changed from 1 to 7 h, the share of recirculating lymphocytes present in blood changes accordingly, from 0.7 to 0.3. Perhaps the above-described effect may be relevant to the phenomenon observed in some cosmonauts ... [middle of sentence omitted in source] ... in the blood stream.

FOR OFFICIAL USE ONLY

SOME RESULTS OF STUDYING THE HUMAN CARDIOVASCULAR SYSTEM DURING ORTHOSTATIC TEST USING SIMULATION MODELING

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 35-37

[Article by V. V. Verigo, A. D. Voskresenskiy and I. V. Arsent'yeva]

[Text] A mathematical model was developed of the human cardiovascular system and regulation thereof in order to simulate transient reactions during the orthostatic test and analysis thereof. The model describes pulsating blood flow, dynamics of changes in intravascular pressure and volume in 34 parts of the cardiovascular system within the cardiac cycle. The vascular network was viewed as a system with concentrated parameters, consisting of 30 segments corresponding to arterial subsystems, venous subsystems, arterial and venous capillaries. Resistive and capacitive properties of vessels, inertial properties of blood, as well as functions of venous valves were taken into consideration. Pumping activity of the heart was described in a four-chamber model by changing in time the specific elasticity of chamber walls.

Hypotheses were expounded on regulation of the cardiovascular system, which explain regulation of heart rate, peripheral resistance, as well as venous tonus and other regulatory parameters.

The model permits testing various hypotheses concerning regulation of the cardiovascular system. In particular, studies were made of transient reactions of the cardiovascular system during the orthostatic test, with a system for the control of factors directed at maintaining cardiovascular homeostasis. The factors were activated proportionately to deviation of arterial pressure from the specified level. It was assumed that there are baroreceptor reflexes from the carotid sinus and aortic arch. Under such conditions, normal circulation of blood was provided by an increase in activity of the sympathetic nervous system and related increase in heart rate, vasoconstriction of elements in the arterial and venous subsystems.

A study of the model revealed that a transient process and ultimate result may differ substantially, depending on the values of different parameters of the vascular system. It was shown that the characteristics of specific elasticity and capacitive properties of vessels exert the main influence on the course of a transient process.

FOR OFFICIAL USE ONLY

Evaluation was made of the time of moving to vertical position on the nature of the transient process in the cardiovascular system and contribution of various elements of nervous regulation to maintaining cardiovascular homeostasis.

In particular, it was shown that, with instantaneous change to vertical position, the most significant changes in the cardiovascular system develop by the end of 10 s: the heart rate increased from 75 to 85/min, pulse pressure dropped from 37 mm Hg to 21 mm Hg, minute volume of circulation diminished from 6 l/min to 3.9 l/min. After removal of regulation of resistance of resistive vessels, the HR rose to 89/mean, pulse pressure showed virtually no change and stroke volume decreased from 80 ml to 39 ml. Minute volume dropped to 3.47 l/min. Inclusion of regulation of the heart rate had virtually no effect on pulse pressure or minute volume. Thus, the model's predictions conformed well with the known physiological data concerning hemodynamic changes during orthostatic tests.

It was demonstrated that this simulation model of the cardiovascular system can be used effectively for the study of functional reactions to gravity factors.



FOR OFFICIAL USE ONLY

BIOMECHANICS OF DISTRIBUTION OF VENTILATION-PERFUSION RATIOS IN THE HUMAN LUNGS  
UNDER THE INFLUENCE OF GRAVITY AND INERTIAL FORCES

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 37-38

[Article by A. M. Genin, A. I. D'yachenko and V. G. Shabel'nikov]

[Text] In studies of the effects of gravity on the human cardiovascular system, attention is usually focused on hydrostatic effects in the systemic circulation. At the same time, gravity has a substantial influence on pulmonary circulation, and the significance of this effect to man's general reactions to weightlessness and accelerations is far from clear.

Our objective was to study by methods of mathematical modeling the biomechanics of pulmonary circulation and lung parenchyma in order to provide a quantitative description of the changes in spatial distribution of ventilation-perfusion relations in the human lung under the influence of gravity and inertial forces differing in magnitude and direction.

In the proposed mathematical model, the gravitational distribution of ventilation and blood flow in the lungs takes into consideration, unlike the models known in the literature, the interdependence of these distributions, distinctions of anatomical structure of pulmonary circulation and nonlinear mechanical characteristics of the lungs. The influence of gravity on distribution of ventilation in the lungs is described with a "liquid-like" model of pulmonary parenchyma, based on the following assumptions: 1) lung tissue filled with air is similar to homogeneous fluid of the same density; 2) the density of pulmonary parenchyma is a function of degree of filling of vessels traversing it and degree of distention of parenchyma; 3) the degree of distention of parenchyma is a function of one scalar variable--transpulmonary pressure, which equals the difference between alveolar pressure and pleural pressure at a given level of the lungs. This function for any segment of parenchyma coincides with the "volume-pressure" curve for the lung as a whole.

A model of stationary flow in an elastic vascular bed with correct dichotomous branching was proposed to describe the distribution of pulmonary blood flow. The morphometric model of the vascular bed was constructed on the basis of data in the literature. The hydrodynamic part of the model takes into consideration the significant contribution of "collapsed" pulmonary capillaries and venous vessels to total resistance of the lungs' vascular bed, as well as vascular resistance as a nonlinear function of transmural pressure.

FOR OFFICIAL USE ONLY

The distributional indexes of ventilation and blood flow, calculated with the model, increase while ventilation-perfusion ratio decreases in the direction of the vector of exogenous forces acting on the lungs; the estimated curves conform quantitatively with published data. It was demonstrated that, even within the third zone of West, there is an appreciable irregularity of the ventilation-perfusion ratio, while irregularity of vascular filling increases irregularity of ventilation by 20%.

The developed model was also used to analyze hypotheses concerning the effects of potential consequences of man's long-term exposure to weightlessness, including increase in elasticity of vessels, decrease in circulating blood volume and other changes in the cardiovascular system, on the nature of distribution of ventilation and blood flow in the lungs after returning to earth. In particular, increased elasticity [extensibility] of vessels should lead to a significant increase in irregularity of perfusion and ventilation-perfusion ratio.

FOR OFFICIAL USE ONLY

STUDIES OF SKELETAL MUSCLES AND MOTOR FUNCTION IN HYPOKINETIC ANIMALS AND MAN

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 39-40

[Article by A. S. Rakhmanov, V. S. Oganov, V. G. Kozlova and V. S. Magedov]

[Text] Analysis of the literature, as well as our studies, warrants the belief that changes in movements of animals and man after a space flight or prolonged hypokinesia are largely related to functional atrophy of skeletal muscles, mainly the antigravity ones. A complex method was developed for examining locomotion of dogs, which combines a dynamomyographic method developed in our laboratory (V. S. Gurfinkel', V. S. Oganov, 1972; V. S. Oganov et al., 1975) with certain traditional neurophysiological and biomechanical procedures, to test this thesis experimentally.

We recorded the exertion and electromyogram of the gastrocnemius and soleus while walking and running on a treadmill in chronic experiments on dogs using an implanted sensor and electrodes. Podogram and goniogram sensors were used for concurrent recording of temporary and time-space characteristics of locomotion.

A model of restricted mobility in a special immobilization system was used to study the effects of relative inactivity of the skeletomuscular system on biomechanics of muscular contraction and locomotion. Analysis of objective data revealed that there was a decline of muscular functional state, as manifested by increased production of electricity by the muscle in standard motor tests and, consequently, diminished electromechanical efficiency of muscles (EMEM).

The obtained data enabled us to establish a correlation between change in muscular function and certain manifestations of disorganized movement. For example, there is every reason to assume that such changes in biomechanics of movement as increase in amplitude and speed of flexion in the ankle joint in animal locomotion after restriction of movement is essentially the consequence of diminished exertion developed by the gastrocnemius. At the same time, some of the changes in kinematic characteristics of limb movement are apparently secondary, and they are interpreted as manifestations of compensatory reactions of the central nervous system, which are directed toward maintaining the set speed of locomotion.

A method was developed for functional determination of the state of human skeletal muscles under dynamic conditions--the Myotest--on the basis of the above-described

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

experimental model and testing of such new criteria as EMEM. We used the parameter of electromechanical efficiency of muscles (reciprocal of ratio of integrated electromyogram to force impulse in the active phase of a test movement performed under standard conditions with a load in the range of 5-15% of the maximum possible exertion) was used for quantitative evaluation of the functional state of muscles.

Clinical trials of this method (49-day experiment on 9 subjects, 182-day experiment on 18 subjects) revealed a significant decrease in electromechanical efficiency of the tested muscles in the course of the experiments. In the group where the usual preventive measures applied, the function of the gastrocnemius was essentially intact throughout the experiment, according to EMEM, and this was apparently indicative of the correct choice of preventive measures.

The described method and criteria can be recommended for evaluation and prediction of the state of skeletal muscles during long-term space flights, as well as to assess the efficacy of preventive measures for the purpose of operational correction thereof.

FOR OFFICIAL USE ONLY

EXCRETION OF CYCLIC NUCLEOTIDES IN URINE UNDER CONDITIONS OF ALTERED GRAVITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICESKOY BIOLOGII I AVIAKOSMICESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 40-42

[Article by L. B. Buravkova]

[Text] It is known that changes in gravity (accelerations, weightlessness) elicit appreciable hormonal changes in man and animals, which are instrumental in adaptation to altered environmental conditions. At the present time the thesis is considered validated that the effects of a number of hormones and neurohormones on the cell are mediated by the system of cyclic nucleotides. Changes in levels of cyclic adenosine-3',5'-monophosphate (cAMP) and cyclic guanosine-3',5'-monophosphate (cGMP) in tissues are reflected in concentration thereof in plasma and excretion in urine. For this reason, a study of the levels of these nucleotides in biological fluids could furnish information about the correlation between different hormonal systems with exposure to such factors.

There are virtually no data in the literature about the metabolism of cyclic nucleotides with altered gravity. Our objective was to examine daily excretion of cAMP and cGMP in urine with exposure to accelerations, prolonged immersion in water and use of preventive factors against the background of immersion.

Experiments were conducted on four subjects (healthy males 25-35 years of age) who were submitted to immersion in water--the method of "dry" submersion developed by Ye. B. Shul'zhenko (1974). During immersion, with the exception of the first 7 days, various conditioning factors were used in a specific order: divided "doses" of accelerations of 0.8-1.6 units in the head-leg direction on the 8th to 14th days; pedaling on bicycle ergometer on the 15th-21st days; combination of divided doses of accelerations and pedaling on the 22d-28th days. Before and after immersion in water, as well as at the end of each cycle of preventive measures, the subjects were exposed to acceleration of 3 units in the head-leg direction for 5 min. Cyclic nucleotides in urine were assayed by the method of competitive protein binding using the sets of the Amersham Company (England).

As shown by the experiments, background levels of excretion of cAMP and cGMP constituted  $3.2 \pm 0.3$   $\mu$ mole/day and  $0.53 \pm 0.18$   $\mu$ mole/day, respectively. Accelerations of 3 units in the background period, after a week of "pure" immersion, as well as after use of preventive measures against the background of immersion in water, elicited a significant increase in excretion of both nucleotides, by 1.7 times for

FOR OFFICIAL USE ONLY

cAMP and 1.4 times for cGMP. This increase is perhaps related to the significant release of catecholamines into blood.

The first day of immersion led to a 40% decrease in excretion of cAMP and 45% increase in excretion of cGMP, followed by phasic fluctuations in excretion of these nucleotides during the 7 days of "pure" immersion. Exposure to divided doses of accelerations daily against the background of immersion elicited a noticeable increase in daily excretion of cAMP, particularly on the 2d-4th day of such exposure, while elevation of cGMP in urine was not as significant. Use of exercise against the background of immersion also led to an increase in cAMP in urine on the 2d-3d day, and excretion of cGMP was higher than under the influence of accelerations. The combination of accelerations and exercise during immersion in water elicited a stable increase in daily excretion of both cyclic nucleotides in urine throughout the week of such treatment.

Thus, the obtained results show that immersion in water, combined with conditioning factors, leads to activation of the hormonal system, with prevalence of the adrenergic element, as a result of which there is an increase in excretion of cyclic nucleotides, particularly cAMP.

FOR OFFICIAL USE ONLY

HORMONAL REGULATION OF FLUID-ELECTROLYTE METABOLISM OF MAN DURING LONG-TERM HYPOKINESIA

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 42-44

[Article by A. I. Grigor'yev, B. R. Dorokhova, G. I. Kozyrevskaya, B. V. Morukov, V. B. Noskov, I. S. Skukina, A. S. Ametov and G. S. Arzamazov]

[Text] Our objective was to study hormonal regulation of fluid-electrolyte metabolism in a healthy man during 182 days of antiorthostatic ( $-4.5^{\circ}$  [tilt of head end of bed]) hypokinesia (AOH). For this purpose, we studied the activity of aldosterone, insulin and parathyroid hormone (PTH) in blood serum using standard test kits--Aldok- $^3\text{H}$ , Tnsik- $^{125}\text{I}$ , PTH- $^{125}\text{I}$  of the Sea-ire-Sorin Firm (France).

It was established that the subjects presented increased sodium excretion during 30-40 days of AOH. On the 26th day and more so on the 46th and 86th days of AOH, there was an increase in aldosterone activity in blood, which was most likely the consequence of a negative sodium balance. During the second half of the experiment, sodium excretion diminished substantially, and in a number of cases it was below the base level. This could have been caused not only by increase in activity of mineralocorticoids. However, in view of the fact that there was no change in glomerular filtration or sodium concentration in blood serum and, consequently, in its filtration charge during AOH, the decrease in sodium excretion could have been attributable only to increased reabsorption thereof in the renal tubules under the influence of increased aldosterone activity and sensitivity to it of renal cells.

In addition to increased sodium excretion at the first stage of AOH, the subjects also presented increased elimination of potassium. It is important that a negative potassium balance was already observed during the first 30 days of AOH and remained high for over 90 days. Evidently, the increase in activity of mineralocorticoids was one of the causes of increased excretion of potassium. However, a negative potassium balance could have an adverse effect on the function of a number of systems. For this reason, upon reaching a certain level of negative potassium balance, there is activation of hormonal systems that normalize it. Insulin is one of these hormones, and it increases potassium transport to cells. Its activity increased in the second half of the experiment, and on the 131st day of AOH it was more than 3 times higher than the base level. The subsequent decrease in potassium excretion can be attributed to this with some share of certainty.

During AOH, there was also an increase in ionized calcium and, after 86 days, of total calcium in blood serum. There was an increase in excretion of calcium in

FOR OFFICIAL USE ONLY

urine, which reached highest levels on the 30th-40th days of AOH. The increase in ionized calcium fraction in blood serum was the result of almost 2-fold increase in PTH activity during the experiment, which caused resorption of bone tissue and increased passage of calcium ions into blood.

On the 2d day of the recovery period, there was high activity of aldosterone and insulin, and apparently as a result of this there was marked decrease in excretion of sodium and potassium. Because of the decrease in blood serum PTH content, there was a decrease in concentration of total and ionized fraction of calcium, while the complex correlations between this hormone and thyrocalcitonin caused a decrease in excretion of calcium in urine.

Thus, these studies enabled us to demonstrate a correlation between changes in activity of aldosterone, insulin and PTH, on the one hand, and changes in fluid-electrolyte metabolism, which occur during prolonged AOH, on the other. It was established that the reaction of the kidneys, tested during prolonged AOH, and change to orthostatic position were consistent with the activity of the tested hormones and directed toward maintaining fluid-electrolyte homeostasis.



FOR OFFICIAL USE ONLY

ROLE OF VOLUME NATRIURETIC REFLEX IN CHANGING RENAL EXCRETION OF FLUID AND ELECTROLYTES WITH GROUND-BASED SIMULATION OF WEIGHTLESSNESS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 44-45

[Article by Yu. I. Ivanov]

[Text] Renal excretion of fluid and electrolytes under normal conditions, as well as after the effects on the legs of an inflatable anti-G suit, during breathing at negative pressure, i.e., with resistance to inspiration (breathing through a filtering gas mask), dry immersion (submersion in water) and with change from orthostatic to clinostatic position, was studied in men and women 19-30 years of age. Concurrently, analogous parameters were examined in a group of essentially healthy individuals before and after increasing the volume of extracellular fluid by intravenous injection of isotonic NaCl solution in an amount of 2% of body mass. The fluid was infused for 40-60 min.

In all studies simulating weightlessness under ground-based conditions, as well as with injection of fluid, we observed about the same increase in urination and excretion of sodium and potassium. In this case, the increased diuresis and natriuresis resulted from decreased tubular reabsorption of fluid and sodium. Glomerular filtration, determined according to endogenous creatinine, underwent insignificant change in all series of tests.

Our study of natriuretic activity of blood plasma, which is an indirect indicator of natriuretic factor level in it, by a method developed in our laboratory (Yu. I. Ivanov, 1976) revealed that in the experiments with compression of the limbs with an inflatable anti-G suit, as well as with infusion of fluid in the vein, there was virtually the same elevation thereof, which indicates that there is virtually identical increase in natriuretic factor of blood plasma under these conditions after stimulation of volume receptors by different methods.

The results indicate that one can use various procedures, which lead to redistribution of blood and increased volume thereof in thoracic vessels, in order to stimulate volume receptors for studies of volume regulation, rather than infuse large amounts of fluid, which is not always possible.

FOR OFFICIAL USE ONLY

MAN'S BODY TEMPERATURE DURING EXERCISE FOLLOWING BRIEF BED REST

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 45-46

[Article by S. V. Rodchenkov]

[Text] It is a distinction of space flights that cosmonauts exercise against a background of hypodynamia. We know from the works of a number of authors (A. Ya. Tizul, 1973; M. Yu. Volkov, L. D. Molchanova, 1977) that bed rest and immersion in water, which are used to simulate weightlessness, elicit a stable drop of body temperature by 0.2-0.4°C. We cannot rule out the possibility that this also occurs during real weightlessness.

However, there is no information in the literature concerning the effect of base temperature at rest on the temperature reaction of the body to subsequent exercise. On the basis of the foregoing, our objective was to investigate man's body temperature during graded exercise following brief bed rest, which induced a drop of deep body temperature.

A total of six young men participated in the studies, in whom we measured rectal temperature (using a thermocouple and automatic recording unit), O<sub>2</sub> uptake, pulmonary ventilation, heart rate and a few other parameters. The subjects exercised on a bicycle ergometer, the loads constituting 30 and 50% of maximum oxygen uptake (MOU) after 1 h of bed rest (a total of 24 studies). The same number of tests on the same subjects, without bed rest preceding exercise, served as a control. MOU was determined by the indirect method with the nomogram of I. Astrand (1960).

One-hour best rest elicited a drop of rectal temperature (with stabilization at the level it reached) from 37.1±0.05 to 36.7±0.07°C, O<sub>2</sub> uptake from 0.34±0.02 to 0.26±0.02 l/min (STPD), pulmonary ventilation from 8.5±0.8 to 5.7±0.3 l/min (BTPS) and heart rate from 74±3 to 57±2/min (p<0.05).

Subsequent exercise on the bicycle ergometer for 50-70 min at air temperature of about 20°C elicited an increase in all measured parameters proportionate to intensity of exercise, with stabilization on the levels reached. The values of the measured parameters during exercise were unrelated to the initial state. Thus, with an exercise load of 30% MOU, rectal temperature was 37.5±0.05°C in the tests with bed rest preceding exercise and 37.52±0.06°C in the control; O<sub>2</sub> uptake was 1.31±0.06 and 1.34±0.06 l/min, pulmonary ventilation 34.6±2.5 and 35.2±2.8 l/min, heart rate 105±2 and 110±4/min (P>0.05). With an exercise load of 50% MOU, these

FOR OFFICIAL USE ONLY

parameters constituted  $37.92 \pm 0.05$  and  $38.00 \pm 0.12^\circ\text{C}$ ,  $1.93 \pm 0.07$  and  $1.81 \pm 0.09$  l/min,  $61.4 \pm 5.8$  and  $62.7 \pm 3.9$  l/min,  $123 \pm 5$  and  $128 \pm 5$ /min, respectively ( $P > 0.05$ ).

Thus, it can be concluded that body temperature during exercise of a constant intensity is unrelated to its base level at rest. It is the absolute level of deep body temperature, rather than degree of temperature elevation, that is regulated during muscular activity.

FOR OFFICIAL USE ONLY

CYTOLOGICAL STUDY OF PERIPHERAL BLOOD ERYTHROCYTES AND LEUKOCYTES FOLLOWING BRIEF SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 46-47

[Article by G. I. Kozinets, V. P. Matviyenko, I. A. Bykova, Z. G. Shishkanova, I. V. Raypolova, S. M. Dul'tsina, L. V. Borzova and O. A. Dyagileva]

[Text] A study was made of 4 cosmonauts who had participated in an 8-day space flight. A cytological examination was made of peripheral blood erythrocytes and leukocytes. The shape and superficial architectonics of erythrocytes were studied by the method of scanning electron microscopy; dry erythrocyte mass was measured by the method of interference microscopy; the electric charge of the erythrocyte surface membrane was determined by the method of cell electrophoresis. The functional properties of leukocytes were examined by means of cytochemical tests (activity of alkaline phosphatase and myeloperoxidase, polysaccharide content by the PAS reaction). Characteristics were obtained that reflected the main functional properties of the cells.

The results of the studies using a scanning electron microscope revealed that a short-term flight had no appreciable effect on the shape of erythrocytes. On the first postflight day, the discocytes [corpuscles?] constituted 87-89%, those with one process 1.5 to 2.0% and pectinate 3.5 to 4.5%. Dyscocytes with numerous processes, dome-shaped, in the form of a mulberry, collapsed ball, spherocytes totaled about 5-6%, cells with degenerative changes constituted about 0.5%. These figures corresponded to preflight levels and the physiological norms.

Interferometric determination of dry mass of erythrocytes yielded data on percentile distribution of erythrocytes as a function of dry mass. Normally, hemoglobin makes up 95.5% of erythrocyte dry mass. On the first postflight day, the distribution of erythrocytes was in the physiological range: 8-28% erythrocytes with dry weight of less than 30 pg, 54-72%--30 to 39 pg, 12-36% 40-49 pg and 0-4% over 50 pg. Similar figures were obtained when blood was tested 14 days after the flight.

The study of electrophoretic mobility of erythrocytes (EME) revealed an average of 10% decrease in EME on the first day after landing, as compared to preflight data. These changes were probably related to the body's stress reaction. In blood samples taken 11 days after the flight, EME conformed with physiological values (1.065-1.138  $\mu\text{m}/\text{cm}$  in  $\text{s}^{-1}$ ).

FOR OFFICIAL USE ONLY

Cytochemical studies of activity of alkaline phosphatase and myeloperoxidase, and polysaccharide levels in granulocytes failed to demonstrate any changes. Some increase in polysaccharides was noted in lymphocytes 14 days after the flight.

These studies indicate that an 8-day space flight has no appreciable influence on morphofunctional properties of peripheral blood cells.

FOR OFFICIAL USE ONLY

DISTINCTIONS OF BLOOD LIPOPROTEIN METABOLISM RELATED TO LIMITED MOTOR ACTIVITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) p 48

[Article by T. A. Kiriyeenko and P. P. Chayalo]

[Text] Restriction of motor activity affects the cardiovascular system (more frequent cardiac ischemia and atherosclerosis). A study was made of the effect of restricted activity on the main parameters of lipoprotein metabolism.

Two series of experiments were conducted on control and experimental rabbits, which were restricted in special cages, for 2 months to study catabolism of intravenously injected cholesterol-labeled lipoproteins of very low (VLDL) and low (LDL) density, obtained from rabbits with alimentary hypercholesterolemia. In addition, determination was made of the composition of the main classes of lipoproteins--VLDL, LDL and high density lipoproteins (HDL) isolated from the blood serum of rabbits by preparative ultracentrifuging, as well as the activity of lipoprotein lipase in blood serum.

It was found that there was slower migration of the radioactive tracer from injected VLDL into LDL and HDL in the experimental animals, which corresponded to diminished activity of blood lipoproteins. This is indicative of slower catabolism of VLDL under hypokinetic conditions. After injection of labeled LDL under hypokinetic conditions, there was delayed elimination from blood of radioactive tracer contained in the LDL fraction. This is indicative of diminished utilization of serum LDL by peripheral tissues.

In addition, there was an increase in total cholesterol, VLDL and LDL in blood under hypodynamic conditions, as well as accumulation in them of cholesterol, triglycerides and protein.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

ADAPTIVE CHANGES IN CORTICAL NEURONS UNDER HYPOKINETIC CONDITIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 48-49

[Article by N. A. Levkova, N. P. Teplyakova and S. A. Kakabadze]

[Text] A study was made of structural and cytochemical changes in pyramidal neurons of the sensorimotor cortex of the rat's cerebral hemispheres in the course of 30-day hypokinesia. Material from 10 control and 30 experimental animals was processed by light, electron microscopy and cytophotometry of nucleic acids. It was established that, by the 10th day of hypokinesia, there is a decrease in mean volume of neurons (by 24.8%), their nuclei, nucleoli (by 37.1 and 34.8%) and nucleoplasmic ratio. Mean nucleic acid content diminished to a lesser extent (by 18%), which corresponded to demonstration of a significant number of "dark" neurons. There were dystrophic changes in neurons and synaptic contacts with signs of destruction. Oligoglial cells presented large heterophagosomes and lipid inclusions. By the end of the experiment, the mean volum of a neuron was close to the control value, while the mean volume of the nucleus increased, and as a whole this caused an increase in nucleoplasmic ratio. There was an increase in nucleic acid content of neurons referable to cytoplasmic RNA, which was indicated by the increase in RNP granule content and enrichment of granular cytoplasmic network.

The obtained data indicate that there is prevalence of reactive changes of a dystrophic nature in pyramidal neurons at the early stage of hypokinesia. Subsequently there is gradual buildup of compensatory structural and metabolic changes involved in adaptation of neurons to new functioning conditions.

FOR OFFICIAL USE ONLY

PLASMA RENIN ACTIVITY AND DIURESIS AS INDICATORS OF CHANGES IN HOMEOSTASIS OF FLUIDS DURING SIMULATION OF SOME ELEMENTS OF WEIGHTLESSNESS WITH ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 49-50

[Article by L. I. Voronin, S. Yu. Yelizarov and N. V. Ulyatovskiy]

[Text]  $+G_x$  accelerations of up to 2.5 G have been proposed to simulate the physiological effects of weightlessness, with the trunk, thighs and legs in a specific position (G. T. Beregovoy et al., 1978). With exposure to such accelerations, many physiological reactions of the cardiovascular system are similar to the reactions to a central volume load inherent in weightlessness and its traditional models. In particular, there is elevation of pressure in the right atrium and right ventricle, and increased delivery of blood to the lungs (A. A. Sergeyev, 1967).

We conducted studies on 16 healthy male volunteers 26 to 40 years old. The subjects were exposed to  $+2.5 G_x$  accelerations, angle of  $90^\circ$  with the thighs at an angle of  $95^\circ$ - $105^\circ$  to the trunk and legs at an angle of  $100^\circ$ - $110^\circ$  to the thighs, for 60 min.

We collected urine for 3-4 h before the start of rotation and immediately after rotation for assay of volume and mean hourly diuresis. We took blood from the ulnar vein before and after exposure to accelerations to assay plasma renin activity (PRA). Before rotation on the centrifuge, blood samples were taken after spending 10-15 min in horizontal position. Blood samples were taken 1-2 min after the centrifuge stopped with the subjects in a position corresponding to body position during rotation with slightly elevated head end of the chair by  $20^\circ$ - $25^\circ$ . PRA was determined by the radioimmune method.

There was a typical 1.7-fold ( $P < 0.05$ ) depression of PRA after exposure to accelerations. This enables us to rule out disorders of the renal stasis or ischemia type in the mechanisms of hypergravitational vasorenal changes, and it is indicative of compensation of hydrostatic forces acting perpendicularly to the longitudinal axis of the trunk, at least in the region of the kidneys. On the other hand, the observed changes in PRA were analogous to those observed when changing from vertical to horizontal position and man submerges in water.

Mean hourly diuresis (MD) during exposure to accelerations showed a 4.6-fold increase ( $P < 0.01$ ), as compared to the initial level. It can be assumed that the



FOR OFFICIAL USE ONLY

increase in diuresis under the influence of +2.5 G<sub>x</sub> accelerations is due primarily to depression of secretion of antidiuretic hormone.

These data indicate that the changes in PRA and MD under the influence of the above accelerations are analogous to the changes observed at the stage of acute reactions of man to weightlessness. The desirability of using such accelerations to simulate the physiological effects of weightlessness was discussed in previous studies (G. T. Beregovoy et al., 1978; N. V. Ulyatovskiy et al., 1978). The chief advantage of such simulation of physiological effects of weightlessness is that, by changing the magnitude and vector of accelerations, it is possible to simulate the physiological effects of all stages of a space flight, including transitional states and the early readaptation period.

FOR OFFICIAL USE ONLY

EFFECTS OF SPACE FLIGHT FACTORS ON BLOOD PROTEIN SPECTRUM

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 51-52

[Article by Ye. V. Guseva and R. Yu. Tashpulatov]

[Text] A study was made of changes in protein spectrum of blood, indicators of humoral and local immunity in cosmonauts after flights differing in duration.

Data were compared after 2-, 6-8-, 16-18-, 49-, 96- and 140-day space flights aboard the Salyut orbital stations and Soyuz type cargo craft. The main protein fractions of blood serum were assayed by the method of radial immunodiffusion in M- and LC-partigen dishes of the Beringwerk Firm.

Examination of protein in the blood of the cosmonauts revealed that dissimilar adaptive changes occurred after flights differing in duration.

The least changes were noted after brief (2 and 6-8 days) space flights.

Space flights lasting 16 and 18 days were associated with the most marked changes in blood protein fractions. There was elevation of all globulin fractions. Among the globulins, there was prevalent increase in the  $\gamma$ -globulin fraction (IgG, A, M), which was indicative of an immune process.

Quantitative changes were demonstrated in fewer protein fractions after the 49-day flight. Distinct changes were referable chiefly to proteins of the  $\gamma$ -globulin fraction and  $\beta_1$ -globulins.

The lack of changes in protein spectrum after the cosmonauts completed 96- and 140-day flights indicated that the body adapted to weightlessness during flights lasting over 3 months, with manifestation of individual disturbances referable to levels of different blood proteins.

After termination of long-germ space flights, the body readapted to earth's conditions. This was manifested by new changes in blood proteins. The greatest changes were noted on the 10th-20th day of the postflight period.

The obtained data revealed that adaptive changes in protein spectrum of blood progress gradually with increase in flight time and affect the largest number of protein fractions by the 16th-18th day. Further extension of flight time was associated with normalization of some blood proteins and significant change in concentration of others.

FOR OFFICIAL USE ONLY

STUDY OF SOME FUNCTIONS IN MAN RELATED TO ALTERED DAILY SCHEDULE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 52-53

[Article by R. I. Bogatova, M. A. Vytchikova and Ye. M. Kuz'micheva]

[Text] The importance of studying the circadian rhythm of different functions of the organism under normal conditions and with a change in daily schedule is not questioned. There are several works in the literature dealing with this question (Ashoff, 1967; A. D. Slonim, 1975; B. S. Alyakrinskiy, 1967, and others).

Our objective was to investigate the nature of circadian changes in some parameters of red and white blood, man's body and skin temperature during isolation in a small chamber with the usual and inverted sleeping-waking schedule.

The studies were conducted in a pressure chamber at normal atmospheric pressure (743-771 mm Hg), air temperature of 25-27°C and relative humidity of 40-70%, and they involved two subjects. For 10 days, the usual 24-h schedule prevailed, with a sleep period from 2330 to 0700 hours; for the next 3 days, the subjects stayed awake continuously, and then followed an inverted schedule (sleeping from 1100 to 1900 hours).

In the course of the study we measured body and skin temperature, and we also assayed hemoglobin, erythrocyte and leukocyte content. We tested the white blood formula.

Both subjects presented the lowest hemoglobin in the mornings and the highest at 0300 hours. Two days after inverting the schedule, the curve changed and maximum hemoglobin content shifted to the morning hours in both subjects.

The circadian changes in parameters of formed white blood elements and total leukocyte count presented some differences, in both the background period and during the time of alteration of daily schedule, with inherent two-peak curves of circadian periodicity of total leukocytes, neutrophils and lymphocytes. After inversion of the schedule the curves remained the same, and a change in rhythm of alterations of white blood parameters was found only at the end of the experiment.

The curve of circadian changes in body and skin temperature with alteration of the daily schedule presented some differences from the curve inherent in the background period.

FOR OFFICIAL USE ONLY

Consequently, inversion of the sleeping-waking schedule elicited certain changes in the subjects' curves of circadian fluctuations of body and skin temperature, as well as morphological composition of blood, which must be taken into consideration when blood samples, body and skin temperature are taken only once.

FOR OFFICIAL USE ONLY

CHANGES IN HUMAN BODY TEMPERATURE DURING THREE-HOUR IMMERSION IN WATER

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 53-54

[Article by M. Yu. Volkov]

[Text] Brief immersion--submersion in water--is sometimes used to simulate weightlessness.

In this study, the volunteer subject's body was isolated from the surrounding liquid with flexible, waterproof film by the method of Ye. B. Shul'zhenko (1975). During each experiment, the following temperatures were continuously recorded graphically: rectal ( $T_r$ ), oral ( $T_o$ ), axillary ( $T_a$ ), external auditory meatus ( $T_{ex}$ ), as well as skin temperature at five points (forehead, neck, chest, waist, thigh) using a unit assembled according to I. M. Bakhilina (1967). The subjects were in vertical position, with air temperature of 24-25°C, before and after 3-h immersion in a tank [tub]. A total of 16 studies were conducted on 8 subjects, with the immersion environment at a temperature of  $33.4 \pm 0.2^\circ\text{C}$  and 8 studies at a temperature of  $36.0 \pm 0.2^\circ\text{C}$ .

In the background period, the following temperatures were noted:  $T_r$   $37.13 \pm 0.06^\circ\text{C}$ ,  $T_o$   $36.70 \pm 0.08^\circ\text{C}$ ,  $T_a$   $36.70 \pm 0.11^\circ\text{C}$  and  $T_{ex}$   $36.51 \pm 0.1^\circ\text{C}$ . There was the usual cranio-caudal gradient of cutaneous temperatures. The temperature sensations were comfortable for the subjects.

During submersion in the immersion liquid at a comfortable temperature ( $33.4^\circ\text{C}$ ),  $T_r$  dropped by  $0.6^\circ$ ,  $T_o$  and  $T_a$  by  $0.3^\circ\text{C}$  for 30-60 min, with subsequent stabilization at the new level. After submerging into a heated immersion environment ( $36.0^\circ\text{C}$ ), there was an  $0.4$  and  $0.3^\circ\text{C}$  drop of  $T_r$  and  $T_o$ , respectively, for the first 30-60 min, followed by rise to base levels.  $T_a$  showed virtually no change. In both series of studies,  $T_{ex}$  exceeded background values by  $0.4^\circ\text{C}$  at the end of submersion. The craniocaudal gradient leveled off, mainly due to elevation of skin temperature in the lower body. Restoration of both deep and superficial temperatures to background levels was observed 30 min after termination of immersion.

According to the subjects' reports, the entire period of immersion at ambient temperature of  $33.4^\circ\text{C}$  was associated with a drowsy state, which was particularly marked for the first 30-60 min and sensation of total thermal comfort. During immersion at  $36.0^\circ\text{C}$ , the subjects reported that they were too warm and even hot. The subjective sensations were confirmed by erythema of the integument and profuse perspiration.

**FOR OFFICIAL USE ONLY**

Our findings are consistent with the data of A. Kleytman (1963) and V. A. Likhtenshteyn (1967), who observed lowering of deep body temperature in man 2-3 h after assuming a horizontal position on a cot under ordinary conditions.

Lowering of deep body temperature, which was marked even with a heated immersion environment, is apparently attributable to limited heat production related to change in tonus of antigravity muscles, and not to drastic intensification of heat transfer into the surrounding water.

FOR OFFICIAL USE ONLY

SOME RESULTS OF PHYSIOLOGICAL EXPERIMENTS CONDUCTED ABOARD COSMOS BIOSATELLITES

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 54-55

[Article by A. M. Genin, Ye. A. Il'in, L. V. Serova, V. V. Portugalov and R. A. Tigranyan]

[Text] Four experiments were conducted on mammals (white laboratory rats) aboard the biosatellites Cosmos-605, 690, 782 and 936. Their main purpose was to study the morphological and biochemical characteristics of organs and tissues of animals exposed to weightlessness in order to determine whether the organism can adapt to these conditions.

The results of physiological, morphological and biochemical studies conducted after the flights indicate that rather long weightlessness (about one-fiftieth of the animal's life) did not elicit pathological structural changes in any of the organs examined. At the same time, animals examined after the flights presented some rather serious functional changes. We refer, first of all, to changes in the skeletomuscular system, such as atrophy of some muscle groups, osteoporosis and diminished strength of osseous tissue. We were impressed by the decrease in ATP activity of myocardial myosin and changes in the erythrocyte system: diminished activity of erythroid hemopoiesis in bone marrow and spleen, shorter life span of erythrocytes and elevation of spontaneous hemolysis level.

Changes were demonstrated in metabolism and hormonal status that warrant evaluation of 18-22-day space flights as moderate stressors. We refer to retardation of animal growth, changes in the hypothalamus, hypophysis, adrenals, gastrointestinal tract and blood.

All of the described changes were reversible; examination of the animals 25 days after returning to earth showed virtually complete normalization of the parameters examined. Weightlessness did not affect the rats' life span or viability of offspring produced by crossing males from the flight group with intact females.

The experiments with mammals conducted aboard biological satellites enabled us to make a comprehensive and detailed assessment of the state of an organism submitted to weightlessness. The obtained data can be used, not only as the basis for theoretical generalizations concerning the mechanisms of action of weightlessness, but in the practical search for measures to prevent its adverse effects.

FOR OFFICIAL USE ONLY

**FOR OFFICIAL USE ONLY**

The high informativeness of experiments conducted aboard biosatellites is largely due to the complex approach used to solve the problems, as well as participation of specialists from diverse institutions of the Soviet Union and foreign countries in setting up and conducting the experiments.



FOR OFFICIAL USE ONLY

METHODOLOGY OF BIOLOGICAL EXPERIMENTS ABOARD THE COSMOS SERIES OF SPECIALIZED EARTH SATELLITES. COMPLEXES OF LIFE SUPPORT SYSTEMS AND SCIENTIFIC RESEARCH EQUIPMENT

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 56-57

[Article by Ye. A. Il'in, B. A. Adamovich, A. A. Zlatorunskiy, A. D. Noskin, V. I. Milyavskiy, V. S. Poleshchuk, V. K. Ovcharov, V. K. Golov, V. S. Magedov, G. N. Pliskovskaya and L. V. Serova]

[Text] The performance of biological experiments aboard automatic space vehicles made it necessary to develop a special methodology, which included the following types of tasks: choice of biological objects and preparation thereof for experiments during space flights; development of biological and engineering specifications for life support systems, as well as equipment for specific scientific studies; development and construction of the above equipment, as well as autonomic and complex biological and engineering testing on the ground; control of flight and synchronous experiments; scientific research at the landing site.

According to the objectives of the studies, the composition of complexes of life support systems and scientific research equipment aboard biosatellites includes the following elements: units for the study and upkeep of rats, different systems of which provide for upkeep of experimental animals (supply of feed and water, elimination and collection of excrements, fur and particles of uneaten feed, partial removal of toxic waste in gas form, recording motor activity and body temperature, illumination of cage); system for regeneration of the atmosphere to furnish animals with oxygen, remove carbondioxide and deleterious gas impurities; gas analysis equipment for measurement of partial oxygen and carbon dioxide pressure, relative humidity, control of operation of regeneration system; unit for heat regulation to maintain the set temperature and humidity conditions, collect and store condensate; unit for controlling the complex.

In addition, scientific research equipment was stowed aboard each specific satellite to conduct special studies.

One of the distinctive features of experiments aboard specialized biosatellites is that it is necessary to conduct ground-based experiments synchronously with the flight ones. These experiments are conducted in full scale mockups of biosatellites, and their purpose is to examine the biological effects of weightlessness by simulating all other space flight factors. In the synchronous experiments,

FOR OFFICIAL USE ONLY

much attention was devoted to the study of parameters of the gas environment of descending vehicles. It must be noted that control of synchronous experiments requires additional automatic communications over the following channels: ground-based measuring complex--control center--test stand. The data obtained from the space vehicle are automatically processed and inputted in the equipment that controls the operation of the systems in the mockup. When conducting biological experiments in space, a number of studies must be conducted right at the landing site of the returnable vehicles, since transportation of biological material to ground-based laboratories takes some time, during which processes of readaptation to earth begin.

For this purpose, constantly changing mobile laboratories were developed, which consist of inflatable compartments with work places for researchers, as well as air conditioning and power supply systems. These complexes are delivered to the landing sites by helicopters, and they permit performance of the required volume of work under comfortable conditions whatever the meteorological situation.

The results of experiments conducted aboard the Cosmos-605, 690, 782 and 936 biosatellites confirmed the validity of the methodological approach to forming specifications for equipment, as well as efficacy of design and technological execution used to develop and construct the equipment.

FOR OFFICIAL USE ONLY

EXPERIMENT WITH ARTIFICIAL GRAVITY ABOARD THE COSMOS-936 BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 58-59

[Article by Ye. A. Il'in, A. M. Genin, V. I. Korol'kov, A. R. Kotovskaya, V. A. Kondrat'yeva, Yu. I. Kondrat'yev, A. A. Shipov, V. S. Oganov, R. A. Tigranyan and V. V. Portugalov]

[Text] Experimental data on validation of artificial gravity as an effective means of preventing the adverse effects of weightlessness were obtained for the first time during an actual space flight aboard the Cosmos-936 biosatellite. The effect of weightlessness on animals was studied on 20 rats that were in stationary life support systems during the flight. A control group of animals (10 rats) was in two onboard centrifuges during the space flight. These animals were exposed to all of the factors of space flight, with the exception of weightlessness.

A set of physiological, biochemical and morphological parameters, obtained after examining the animals a few hours after the descent vehicle landed and during the period of readaptation to earth's gravity, served as the criterion for evaluating the experimental results.

Examination of animals who were exposed to artificial gravity during the space flight revealed that their coats were cleaner, they presented a good orienting reaction and were more active. During the readaptation period, these animals showed no retardation of weight gain, and diminished static endurance was restored by the 6th day.

Long-term stays on rotating centrifuges led to an increase in latency period of the nystagmic reaction, diminished duration and frequency of nystagmus.

Use of artificial gravity made it possible to preserve the base values of parameters characterizing postural motor reactions and the lift [elevator] reflex.

This group of animals presented rather high nonspecific immunoreactivity, which was manifested by absence of Proteus dysbacteriosis.

Artificial gravity prevented appreciably the decrease or increase in force of contraction and efficiency of muscle fibers of the anterior extremities, which occur in weightlessness, as well as attenuated the adverse effect of weightlessness on the myocardium; it prevented development of hypofunction of the thyroid,

FOR OFFICIAL USE ONLY

changes in intervertebral ganglia and spinal cord tissue, as well as development of an acute stress reaction at the early postflight stage.

Artificial gravity also had some effect on the bone system: less marked decline of ash index and decline of stable calcium and phosphorus; no redistribution of calcium and phosphorus in the epiphysis and diaphysis of long bones.

Thus, use of artificial gravity of 1 G in the course of an 18.5-day space flight had a preventive effect on the deleterious action of weightlessness.

FOR OFFICIAL USE ONLY

STATE OF HIGHER NERVOUS ACTIVITY OF ANIMALS FOLLOWING FLIGHTS ABOARD BIOSATELLITES

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 59-60

[Article by N. N. Livshits, Z. I. Apanasenko, M. A. Kuznetsova and Ye. S. Meyzerov]

[Text] Studies of behavioral reactions of albino rats when presenting them with tasks differing in difficulty revealed that there was deterioration of efficiency of higher branches of the brain after 19-22-day flights aboard biosatellites of the Cosmos series. There was an increased number of refusals to perform the tasks, and a longer time was required to perform them; there was also an increase in mistakes made, more frequent neurotic signs and deviations from normal dynamics of mistakes during the test, with impairment of adequate inhibitory reaction to an exogenous stimulus. The capacity for forming new temporary associations was retained, but there was greater fatigability, with change in strength and correlation between the main neural processes.

Exposure of animals to additional factors (irradiation, implantation of foreign bodies in the abdomen) is not indifferent, and they have an effect as elements of a complex stimulus. The associated changes in higher nervous activity were governed by the general laws of reactions to a complex factor, and they were related to the correlation between components.

Use of artificial gravity aboard the spacecraft (Cosmos-936) as a preventive measure against the adverse effects of weightlessness was ineffective for higher nervous activity. On the contrary, animals submitted to centrifuging experienced more difficulty in recovering already existing skills and presented a reliably poorer ability for solving new problems.

Centrifuging also had an adverse effect (though to a lesser extent) in model experiments on earth.

There is reason to believe that the possible positive effect of artificial gravity during a space flight is depressed and overlapped by the adverse influence on the central nervous system of angular velocities that occur during centrifuging. This influence is more demonstrable when the animals perform more complicated tasks making increased demands of the brain's analytical and synthetic functions. Moreover, angular velocities, which act through the vestibular system, apparently make it all the more difficult to solve problems, the finer spatial orientation is needed for them.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Evidently, such sensitivity of the central nervous system to factors associated with artificial gravity must be taken into consideration when developing preventive measures.

FOR OFFICIAL USE ONLY

ELECTRON MICROSCOPIC STUDY OF RAT PANCREAS AFTER SPACE FLIGHT ABOARD THE COSMOS-936  
BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 60-62

[Article by G. G. Sheyanov and V. A. Gulyayev]

[Text] In the event of onset of morphofunctional deficiency of the endocrine part of the pancreas, which is one of the most important regulators of intermediate metabolism, one would expect that the reserve capacities of an organism would be drastically limited in an extreme situation. This work deals with a study of the condition of this gland under rather unusual living conditions--during a long-term space flight.

Studies of ultrastructure of pancreas cells of rats exposed to the overall effect of space flight factors, with or without centrifuging, revealed that there was dilatation of reticulum cisternae and perinuclear space in acinous cells, with formation of ShER [expansion unknown] vesicular structures, shortening of reticulum tubules, formation in cytoplasm of cytolysomes, myelinoid structures, clearing and swelling of mitochondria, shortening and destruction of their cristae. In all of the flight series, changes in insulino-genic B cells were demonstrable by clearing of the mitochondrial matrix, vacuolization of cytoplasm, aggregation of granules, rupture of their membranes and dilatation of Golgi's system tubules. Intensive proliferation of collagen bundles was evident in capillaries adjacent to B cells, in their pericapillary spaces. All this was indicative of depression of secretory processes and possible onset of relative insulin deficiency. The most serious finding in all animals of the flight series was complete disappearance of the population of A cells. If we consider that, under ordinary conditions, one-third of the islets of Langerhans consists of A cells, there accidental absence on sections in studies of the islets of 15 rats appears unlikely, particularly since these cells were found in the group of animals in the synchronous ground-based control. There were numerous transient forms of cells on the boundary between islet and acinous tissue of rats in the flight group: cells with signs of both exocrine and endocrine B cells. Cellular IER [expansion unknown] is vesiculated, and there are transient forms between these vesicles and B granules, i.e., in response to disappearance of part of the endocrine tissue in the pancreas, it is restored by means of transformation of exocrine epithelium. The fact that, in response to disappearance of A cells there was first addition to the population of B cell is apparently related to the fact that, along with destruction of A cells there must be development of hyperglucagonemia, which is

FOR OFFICIAL USE ONLY

tantamount to insulin deficiency for the organism. A cells appeared in the islets of all animals 25 days after the vehicle was returned to earth; the number thereof was appreciably lower in animals that were not submitted to centrifuging than those that were, let alone the control rats. It must be noted that the process of transformation of exocrine epithelium into endocrine in rats submitted to centrifuging during the flight was appreciably less marked at the time they landed. Evidently, the disappearance of A cells occurred at the early stages of flight; creation of artificial gravity caused early onset of repair, so that they began to reappear and, by the time the rats were sacrificed on earth, after a certain readapation period, there was fuller recovery of the population of cells that had previously disappeared. The demonstrated changes occurred under the cumulative effect of all flight factors could not be prevented by centrifuging, and they cannot be attributed to hypokinesia, since the pancreas of animals in the synchronous ground-based control experiment presented all types of changes, while ultrastructural changes in their organelles were not excessive.



FOR OFFICIAL USE ONLY

STRUCTURE OF THE SMALL INTESTINAL MUCOSA OF RATS AFTER SPACE FLIGHT ABOARD THE COSMOS-936 BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 62-63

[Article by R. A. Brodskiy, N. D. Yakovleva, L. N. Bandurko and N. A. Pogudina]

[Text] Our previous studies of the small intestine of rats flown aboard the Cosmos-782 biosatellite revealed a number of nonspecific destructive changes in this organ. Our objective here was to investigate the distinctions of changes in the small intestine of animals in an analogous flight with the use of artificial gravity.

Segments of the duodenum, proximal, medial and distal parts of the small intestine of 36 rats, who spent 20 days aboard the artificial earth satellite, with the use of artificial gravity, in a ground-based synchronous experiment with and without centrifuge and vivarium control were submitted to histological, histochemical and electron microscopic analysis. The material was studied within the first few hours after landing and after 26 days of readaptation to earth.

Histological examination of the wall of the small intestine failed to reveal noticeable changes in its structure. There was only some increase in number of intra-epithelial lymphocytes in the basal (sometimes supranuclear) region of enterocytes of animals in the experimental groups.

Histochemical studies revealed an increase in activity of leucine aminopeptidase in the brush [striated] border of the small intestine of experimental groups of rats, which was particularly evident in the central section; it also remained high in the readaptation period. Acid phosphatase activity was elevated in enterocytes, in the stromal cells at the apices of the villi, due both to an increase in enzyme-containing cells and amount of granular reaction product in cells.

The data obtained from electron microscopy of the central part of the small intestine revealed that destruction of microvilli was inherent in all experimental groups of animals. Some regions were swollen, rounded and constricted in the form of vesicles differing in size and density, so that isolated enterocytes or a group of adjacent cells were wanting in microvilli. Such enterocytes were notable for containing many polymorphous vesicles, large mitochondria with lyzed cristae, more marked dilatation of the endoplasmic reticulum, accumulation of lipid drops, and they were situated on the surface of the epithelium without coming in contact with the basement membrane. The impression was gained that the enterocytes

FOR OFFICIAL USE ONLY

were "ejected" from the epithelium, not only at the apex as occurs normally, but on the lateral surface of the villi. All of the experimental groups of animals also presented the phenomenon of fragmentation of basal segments of enterocytes of the lower and middle third of the villi, which had not been described previously in the literature.

With reference to the stroma of the mucous membrane of the small intestine, there was moderate pericapillary edema in the region of the crypts, accumulation of droplets of lipids in the intercellular spaces and perivascular connective tissue.

The described changes in the wall of the small intestine of rats flown in space and in the synchronous ground-based experiment were similar, although they were more marked in the flight group and disappeared more slowly during the readaptation period. The irreversible lesions to some structures were apparently due to the combined effect of space flight factors. Creation of artificial gravity aboard the biosatellite with a centrifuge did not alter the direction of destructive processes in the wall of the small intestine.

FOR OFFICIAL USE ONLY

ION REGULATING FUNCTION OF ANIMAL KIDNEYS AFTER FLIGHT ABOARD THE COSMOS-936  
BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 64-65

[Article by Yu. V. Natochin, N. A. Ilyushko, Yu. I. Kondrat'yev, Ye. A. Lavrova and Ye. I. Shakhmatova]

[Text] The method of balance tests was used to study fluid-electrolyte metabolism in albino rats after space flights aboard biosatellites (Cosmos-605, 690, 782) (N. A. Ilyushko et al., 1975, 1977); evaluation of fluid-electrolyte metabolism after the flight aboard Cosmos-936 was made with the use of water and salt loads. It should be noted that the diet and upkeep of rats during the period of flight in life support systems were virtually identical in all of the flight and ground-based model experiments.

The water load test was performed to assess the osmoregulatory system and degree of possible fluid deficiency. On the first postflight day, excretion of the water load was increased in rats submitted to weightlessness, as compared to the synchronous experiment ( $P < 0.02$ ). On the 4th day of the readaptation period, elimination of fluid after the water test was lower in flight animals submitted to weightlessness ( $P < 0.01$ ) and to gravity ( $P < 0.02$ ) during the flight, as compared to the animals in the synchronous experiment. A comparison of the examined groups with regard to dynamics of development of the diuretic reaction and magnitude of maximum water diuresis failed to reveal reliable differences.

As we know, the distinction of man's reaction to a water load is that there is postflight decrease in elimination of fluid and maximum diuresis (A. I. Girgor'yev et al., 1976). Evidently, the cause of the differences in human and animal reactions to the water test on the first day of readaptation is that, because of man's vertical position, there is marked redistribution of fluid after returning to earth's gravity, which is one of the important factors causing fluid retention in the body.

The decreased elimination of fluid after the water load by both groups of flight animals on the 4th day of readaptation is probably related to maximum retention of electrolytes at this time. Thus, after the flight aboard the Cosmos-605 biosatellite, maximum retention of sodium, potassium and calcium was noted on the 4th-5th day of readaptation, and after the flight aboard Cosmos-782, on the 2d day of readaptation.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

The studies of excretion of a potassium load after a space flight, conducted for the first time, were of great interest with regard to describing potassium metabolism. Elimination of potassium on the 2d day of readaptation was the highest in rats submitted to weightlessness, as compared to the synchronous experiment ( $P < 0.01$ ) and exposure to artificial gravity ( $P < 0.02$ ). In the latter case, excretion of potassium did not differ from the synchronous ground-based experiment. On the 5th postlanding day, no differences in this parameter were demonstrated. A study of potassium content in different parts of the kidney revealed that it was low after the flight in the wet substance of the cortex ( $P < 0.001$ ), external and internal medullary substance of the kidney ( $P < 0.01$ ), as compared to the synchronous experiment. The changes were less marked in rats kept on the centrifuge during flight, and as compared to the control none was demonstrable in the renal cortex, but they were present in the medullary layer ( $P < 0.05$ ). The obtained data warrant the assumption that a potassium load permits evaluation of the organism's ability to deposit potassium. With decrease in volume of the reservoir, perhaps due to atrophy of chiefly muscle cells, there is increase in excretion of potassium, and this was demonstrable after the flight. Thus, the postflight changes in fluid-electrolyte metabolism of animals were largely determined by changes in metabolic processes.

FOR OFFICIAL USE ONLY

EFFECT OF FLIGHT ABOARD THE COSMOS-936 BIOSATELLITE ON BIOENERGETICS OF ANIMALS' SKELETAL MUSCLES

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 65-67

[Article by E. S. Mailyan, Ye. A. Kovalenko, L. B. Buravkova and L. V. Kokoreva]

[Text] It is known that all forms of energy expended at rest and during active activity include energy spent on overcoming earth's gravity. Hence, the smaller load on the muscular system in the absence of gravity could alter the nature and intensity of bioenergetic processes, which are entirely determined by the organism's energy requirements.

Polarograph analysis was made of respiration of mitochondria isolated from the posterior group of femoral muscles of rats flown in space for 18.5 days, in order to study oxidative and energy metabolism in muscles. Determination of respiratory characteristics of mitochondria in different metabolic states demonstrated the dynamics of changes in tissular respiration of muscles in the postflight period.

On the first day (10 h after landing) the rate of substrate respiration was lower in the flight group than the synchronous one. Inhibition of respiration was observed with the use of both NAD-dependent substrates ( $\alpha$ -ketoglutaric and glutamic acids) and succinic acid. The rate of respiration diminished by 26, 29 and 42%, respectively ( $P < 0.01$ ). This pattern was even more marked when we determined ADP-dependent respiration, which reproduces in a cell the metabolic state of tissue during muscular contraction and is an indicator of energy-related adequacy of respiration, since it reflects the state of the chain of accumulation of energy. The rate of respiration in the presence of ADP was 44% lower in the flight group than the synchronous one ( $P < 0.001$ , succinate as the substrate of respiration), 46% lower ( $P < 0.05$ —glutamate) and 34% lower ( $P < 0.01$ — $\alpha$ -ketoglutarate). There was no change in the respiratory control.

On the 25th postflight day, these changes disappeared in the flight group; the rate of substrate and phosphorylative respiration was close to the levels in the synchronous group, with some signs of supercompensation.

Determination was made of total lactate dehydrogenase activity to examine glycolytic processes in muscles. We found that LDH activity was 47% lower ( $P < 0.01$ ) on the first day of readaptation than in the synchronous group and vivarium control. On the 25th day, enzyme activity increased significantly, and even exceeded the control with statistical reliability.

FOR OFFICIAL USE ONLY

Thus, a comparison of the rate of reactions and orientation of different stages of oxidative and energy metabolism in mixed muscles reveals phasic changes in the postflight period: depression of oxidative metabolism and glycolysis on the first days and recovery thereof on the 25th day of the readaptation period. The sequence of events in the readaptation period is apparently determined by the systemic mechanism of adaptation. It may be considered that depression of substrate and phosphorylative respiration in muscles for the first few days after returning to earth's gravity, being the cause of insufficient ATP synthesis, stimulates metabolic processes aimed at adaptation to the higher functioning level. This increases functional activity and biogenesis of mitochondria. With increase in strength of the mitochondrial system, there is also increase in ATP production per unit tissue mass, and the ATP deficiency is eliminated.

FOR OFFICIAL USE ONLY

STUDY OF CONTRACTILE FUNCTION OF MUSCLE PROTEINS ON THE MODEL OF GLYCERINATED FIBERS  
IN AN EXPERIMENT ABOARD THE COSMOS-936 BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 67-68

[Article by S. A. Skuratova, V. S. Oganov and M. A. Shirvinskaya]

[Text] Previous studies aboard the Cosmos series of biosatellites demonstrated changes in functional characteristics of muscular contraction in a whole muscle preparation (V. S. Oganov, A. N. Potapov, 1976), which reflected the corresponding structural and metabolic changes in muscles during space flight (Ye. I. Il'ina-Kakuyeva, 1977; V. V. Portugalov, N. V. Petrova, 1976).

Our objective here was to determine, for the purpose of further deepening of research, the degree to which "functional atrophy" of a whole muscle in weightlessness is related to changes in contractile properties of myofibrillar proteins, and to assess the effect of artificial gravity (AG) on the function of skeletal muscles that undergo changes during a space flight.

We used bundles of glycerinated fibers from muscles of the hind leg to perform both tasks in an experiment aboard the Cosmos-936 biosatellite: slow, soleus muscle (SM) and rapid, long extensor of the digits (LE), as well as the foreleg: slow, medial head of the brachial triceps (MHBT) and fast, brachial (BM). We used a method (A. Szent-Gyorgyi, 1949) with the modifications proposed by Specketal (1961) and Sexton (1967) for muscles of warm-blooded animals, for processing and biometry of the preparations. Appropriate solutions were used for isometric contraction of glycerinated muscle fibers under the influence of ATP: one for contracting, using the formula of Bendoll (1970) and for relaxation, according to A. Ye. Bukatina (1971). A type 6MKh1B mechanotron was used to record contractions. The experimental data were submitted to statistical processing using the criterion of Student.

The results of these studies revealed that there was a decrease in force of contraction and efficiency of muscle fibers of antigravity slow muscles of the hind and fore legs, particularly marked in the soleus, under the influence of the space flight. Some elevation of these parameters was noted in fiber preparations from rapid muscles of the front and hind limbs, particularly marked in the brachial muscle.

Acceleration of the process of development of contraction of both slow muscles was demonstrated in a study of time characteristics, and it occurred in the SM due to shortening of both phases of contraction and in the MHBT due to the slow phase.

FOR OFFICIAL USE ONLY

- There was slowing of the process of development of contraction in the fast muscle of the hind leg (LE).

AG prevented virtually all changes in strength, efficiency and rate of contraction of glycerinated muscle fibers of the foreleg observed in the animals under the influence of weightlessness.

- On the whole, the results of these studies indicate that the type of reaction of the contractile system of different muscles to space flight factors is largely determined by the functional specialization of muscles and biomechanical conditions of their contraction, and the severity of this reaction depends on the degree of involvement of the muscles in antigravity function on earth. Our findings warrant the assumption that functional atrophy in muscles of the slow type, previously demonstrated in a whole muscle preparation (V. S. Oganov, A. N. Potapov, 1976), is related to changes in properties of myofibrillar and, most probably, only regulatory proteins. The described changes are highly specific and adaptive, which is confirmed by the marked preventive effect of AG. The results of this work helped gain better understanding of the mechanisms of changes in skeletal muscles and motor functions of cosmonauts, as well as in developing methods for evaluating the condition of muscles and preventive measures.



FOR OFFICIAL USE ONLY

EFFECT OF ARTIFICIAL GRAVITY ON MORPHOLOGICAL MANIFESTATIONS OF ANIMAL REACTIONS  
AFTER FLIGHT ABOARD THE COSMOS-936 BIOSATELLITE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 69-70

[Article by Ye. A. Savina, Ye. I. Alekseyev, V. I. Yakovleva and G. I.  
Plakhuta-Plakutina]

[Text] Production of artificial gravity aboard the Cosmos-936 biosatellite made  
it possible, for the first time, to single out the effect of weightlessness from  
the overall set of space flight conditions, and to assess the role of returning  
to earth's gravity as one of the stress factors related to the animals' return to  
earth.

The adenohipophysis and "target" glands--adrenals and thyroid--as well as lungs of  
rats flown aboard Cosmos-936 and sacrificed 4.5-9 h after the flight, served as  
material for histological and morphometric studies. Animals in ground-based  
model experiments and intact rats served as a control.

The findings revealed that weightlessness did not elicit appreciable structural  
changes on the organic and cellular levels. This was indicated, in particular,  
by the absence of pathological forms of cells in the adenohipophysis, which  
usually appear in the presence of prolonged impairment of hormone production, as  
well as the condition of "target" glands under its control. All of the demon-  
strated changes were referable to the category of functional ones, since they  
leveled off as the time of return to earth increased.

A comparison of the findings on endocrine glands of rats submitted to weightlessness  
and artificial gravity established that the return to earth's gravity after long-  
term weightlessness elicited development of an acute stress reaction (gravity  
stress). This was indicated by morphological signs of transformation and degranu-  
lation of glandular elements of the adenohipophysis, delipoidization of the adrenal  
cortex, increase in population of calcitonin-secreting cells and size of their  
nuclei in the thyroid, as well as increase in number of leukocytes in vessels and  
stroma of the lungs.

Use of artificial gravity leveled off the changes induced by weightlessness in the  
thyroid and adenohipophysis-adrenal cortex system and thus increased the animals'  
resistance to acute stressors. The morphological signs of acute stress reaction

FOR OFFICIAL USE ONLY

were not demonstrable at all (for example in the adrenals) or were considerably less marked (in the lungs) in rats who were on the centrifuge during the flight. Thus, use of artificial gravity revealed that, among the factors that elicit an acute stress reaction in animals after a flight, return to earth's gravity plays the leading role.

80  
FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

EXPERIMENTS CONDUCTED ABOARD THE SALYUT-6 ORBITAL STATION WITH BIOLOGICAL OBJECTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZHNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 70-71

[Article by G. P. Parfenov, M. G. Tairbekov, R. N. Platonova, V. P. Zhvalikovskaya, V. M. Abramova, A. V. Rostopshina and E. A. Oygenblik]

[Text] Among other experiments involving the cosmonauts during the first and second missions aboard the Salyut-6 orbital station, there were experiments with the *Tr. castaneum* rust-red flour beetle and with *E. coli*.

The flour beetles were studied with respect to survival, duration and nature of development, and mutability of embryonic cells. It was established that space flight factors and, in particular, weightlessness do not prevent normal development of the flour beetle, as it appears, and all ovicells with central position of embryo and uniform cleavage. The time of development of specimens of this species and their survival at different stages of development were close to normal. Weightlessness did not elicit hereditary changes in either male or female gametes of the beetles. More precisely, it did not elicit changes that are considered to be dominant lethals. It can be considered that the purpose of the experiments with the flour beetle was achieved.

In the experiments with *E. coli*, studies were made of conjugation of bacterial cells and associated transmission of extrachromosomal genetic elements--plasmids. It was established that this process occurs at the same rate and frequency in weightlessness as on earth.

Biochemical studies helped determine that the swelling and some destruction of mitochondria observed in weightlessness are related to reduction of processes of aerobic oxidation. This decline is adaptive in nature, it is reversible, and it leaves no structural trace in the cell.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

EFFECT OF CLINOSTATING OF ETIOLATE ARABIDOPSIS SEEDLINGS ON SOME PARAMETERS OF PLANT FERTILITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 71-72

[Article by V. M. Abramova, S. A. Poltavskaya and G. P. Parfenov]

[Text] Studies of the effects of weightlessness on higher plants revealed a difference in emphasis: in the onboard experiments there was predominant demonstration of genetic changes, and in laboratory experiments using centrifuges and clinostats, there was prevalence of physiological changes and tropism. This inconsistency must be eliminated.

Our objective was to obtain information about the effect of clinostating on a set of quantitative parameters of plant fertility, which included both genetic and nongenetic embryogenetic anomalies.

Arabidopsis seedlings cultivated by the standard method (V. I. Ivanov, 1974), with continuous clinostating (10 r/min) and in the absence of light, served as the object of our study. Germination time in the experiment ranged from 3 to 9 days. The maximum corresponds to one-fourth the life span of this plant.

The orientation of etiolated seedlings cultivated in the clinostat was disorganized; it was also noted that 5-6-day-old seedlings had virtually no connection between their roots and the substrate. By the 7th day, control plants were also spread over the surface of the agar, but the roots penetrated deep into the substrate.

After staying in the clinostat, the etiolate seedlings were kept in the light for 1 day, transplanted into soil and raised until they bore fruit. Analysis was made of the offspring using the embryo test (Muller) in the first 3-10 pods of the main stalk.

The results were indicative of a reduction in number of normal offspring, which was not quite at random, in plants raised from seedlings after 7 days in the clinostat, as compared to the control. The reliable decrease in number of normal seeds in the offspring of experimental first generation plants was not always associated with an increase in number of sterile ovules or death of embryos at different stages of embryogenesis.

The obtained data warrant the conclusion that some elementary genetic processes during plant development may depend on gravity.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

STUDY OF THE BIOLOGICAL EFFECTS OF SPACE FACTORS ON REPRESENTATIVES OF THE ANIMAL KINGDOM

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 72-73

[Article by V. A. Dushkin]

[Text] Biological studies of new factors related to man's endeavors always start with experiments on animals. The fullest information is obtained from comparative studies, when experiments are performed on animals of different classes.

One can differentiate three categories of research in the study of biological effects of space factors on an organism: 1) determination of general biological effects of the space environment; 2) determination of the influence of sequelae of space environment effects on the organism during flight and in the postflight readaptation period; 3) determination of long-term sequelae of effects of space factors on animals.

In the first case, the studies can be conducted on any species of animals, with consideration of technical possibilities of life support in space. The more animal species are submitted to a comparative test, with regard to space environment factors, the more demonstration there will be of the biological patterns of space ecology.

The studies of dogs and rats conducted in space revealed that the morphological and functional changes that appeared in the animals under flight conditions were reversible, and return to normal occurred at the same time as in analogous ground-based experiments. This pattern shows that comparative studies of the biological effects of space factors on different species of animals can be conducted in ground-based experiments, without resorting to sending most animal species into space.

In the second case, it is preferable to study animal species that adapt well to changing environmental factors. High adaptability is inherent in rats, dogs, mice and pigs; it is less marked in rabbits, monkeys and guinea pigs. With this in mind, it was quite justified that the first studies aboard Soviet satellites were conducted on dogs, while subsequent experiments are being conducted mainly on rats.

In the third case, the studies can also be conducted on animal species with good adaptability. But here it is important to study animals of a specific genotype

FOR OFFICIAL USE ONLY

more often. For example, there may be oncogenic sequelae from space factors in inbred strains of mice, which are the opposite in frequency of spontaneous neoplasms. In this instance, it is more convenient to study the mutagenic effect on strains of mice that differ in sensitivity to physical mutagenic factors.

It is promising to make a biological study of space effects on pigs. Aside from the fact that this species has many morphophysiological features similar to man's, it may turn out to be an important element of the cosmonaut's ecological system. Such studies can be pursued on miniature pigs in different weight categories, the breeding of which has been developed in the Scientific Research Laboratory of Experimental Biological Models, USSR Academy of Medical Sciences.

FOR OFFICIAL USE ONLY

ADAPTATION TO USUAL AND UNUSUAL MECHANICAL CONDITIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 73-75

[Article by G. L. Komendantov, K. A. Pimenova and V. N. Razsudov]

[Text] As we know, everything living on our planet appeared and developed under specific conditions, including mechanical ones (in the ocean, on land). The latter refers to the constantly present earth's gravity and periodic effects of inertial forces that arise when man and animals move actively in space.

Organisms adapted to these mechanical conditions in the course of evolutionary development, to the extent of development of so-called "mechanical immunity" (I. P. Pavlov).

At all stages of development of mankind, scientific and technical progress was related, in particular, with the creation of various means of transportation, during the use of which man is exposed to mechanical forces, which impart to his body accelerations differing in characteristics, alternation of low accelerations and weightlessness, etc. All this lowers the efficiency [fitness for work] of personnel who operate them (pilots, flyers, cosmonauts, etc.), and renders the conditions for passengers less comfortable. The problem of adapting to these unusual mechanical conditions, especially for operators, in the course of long-term space flights and when working on interplanetary stations acquires much importance (adaptation and acclimatization as a degree of adjustment).

The systems approach to this problem enabled us to identify the system of the body to which mechanical stimuli address themselves primarily--the functional system that perceives space and fulfills the function of equilibrium, with its somatic, autonomic and sensory elements.

Theoretical analysis of this problem led us to expound a hypothesis that a new functional system, which perceives space and implements the function of equilibrium, of a "disperse nature" (G. L. Komendantov, K. A. Pimenova, 1973), appears in man in the course of adaptation in the course of long-term exposure to weightlessness, for example, in "celestial settlements."

In experiments on animals it was found that the sympathetic nervous system and reticular formation play a substantial role in the process of adaptation to

FOR OFFICIAL USE ONLY

unusual mechanical conditions (simulating "bumpy" flight) (L. I. Chernikova, 1972, 1978), as a subsystem of the general functional system of the central nervous system regulating all functions of the body and combining them into a single functional whole.

Reproduction of the nervous coordinations that occur when man falls under ground-based conditions is a promising route for developing an effective model of weightlessness.

Immersion with simultaneous rotation of the "tank" with the tested subject should be used to create such a model of weightlessness (G. L. Komendantov, N. A. Razsolov, 1977, 1978). During prolonged simulation, the subject develops a stress state--the overall reaction of the body occurring with adaptive and trophic regulation of all body functions, with which there is change not only in functions, but trophic properties of tissues.

There is something general and something specific in the process of adaptation to accelerations and weightlessness, i.e., elements that are inherent only in weightlessness or only in accelerations. In the future, the existing methods of preventing the adverse effects of weightlessness could be used to soften the process of man's adaptation to weightlessness when people migrate to "celestial settlements," or small planets, including artificial ones.

It will be necessary to develop in people a new specific system, which would perceive space and serve for the function of equilibrium, in order to conquer planets with a greater mass than the planet earth.



FOR OFFICIAL USE ONLY

THE FIRST EXPERIMENTS IN THE USSR DEALING WITH THE STUDY OF EFFECTS OF ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 75-76

[Article by A. A. Sergeyev]

[Text] As far back as 1876, K. E. Tsiolkovskiy, expounding the idea of interplanetary travel, arrived at the conclusion that the flights of spacecraft and astronauts in them would be exposed to the effects of accelerations. Having erected a "rotating machine" and conducted a number of experiments with insects and chicks in it, he proved the effectiveness of gravity acceleration.

In view of the increasing speed of modern aircraft, Prof N. A. Rynin of the Institute of Railways concluded in 1928 that the problem of effects of accelerations is also important in aviation.

On the basis of the thesis of K. E. Tsiolkovskiy that the centrifuge is only experimental method for studying the effects of accelerations, N. A. Rynin developed in 1928 two centrifuges with a short radius of action, and he organized a special research team, which included N. A. Rynin, A. A. Likhachev, V. M. Karasik, A. A. Sergeyev and I. N. Stamerov, engineer.

During 1928-1931, this team conducted a series of experiments on insects, fish, reptiles, birds and some mammals to determine the effects of accelerations. The main flaw in the set-up of these experiments was that it was absolutely impossible to place any physiological instruments on these centrifuges to examine the results of the observed effects.

For this reason, the studies focused more on the magnitude and duration of the accelerations than on the direction, i.e., on determination of the range of endurance thereof. As a result, the researchers succeeded in establishing the range of endurance of accelerations by different species of animals. The use of the comparative physiological approach, which had been used for the first time, is the main importance of those studies.

Because the team was dissatisfied with the results of their studies (impossibility of using physiological instruments), they were prompted to work on development of a more refined centrifuge with the intent of possible use thereof for man as well. This is how the idea was conceived to design a large centrifuge, and in 1934

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

an enormous set of working blueprints of all parts of this machine, guaranteeing the possibility of 20-fold accelerations in different directions (extrapolated to the position of a man) was delivered to the management of the Scientific Research Institute of the Civil Aviation.

FOR OFFICIAL USE ONLY

EFFECT OF LONG-TERM  $+G_z$  ACCELERATIONS ON EFFICIENCY AND SOME PHYSIOLOGICAL PARAMETERS OF OPERATORS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 76-78

[Article by Yu. Yashin, V. M. Tardov, Yu. S. Miroshnikov and Ye. A. Degtyarev]

[Text] It is known that maximum accelerations during flight can reach 8-9 units, which has a substantial effect on pilot efficiency. For this reason, a number of studies have been conducted in recent times, dealing with the performance of an operator exposed to accelerations. At the same time, some aspects of the effects of  $+G_z$  high level accelerations on the specific operator work of a pilot have not yet been sufficiently investigated.

We studied the effects of  $+G_z$  accelerations on efficiency and some physiological parameters of operators.

The studies were conducted on a flight simulator complex, which included a centrifuge with 8 m arm and electronic computer.

To assess operator efficiency, we used as a test the task of tracking a light mark that moved when signaled by the computer. An ordinary control stick was used to compensate for deviations of the mark.

Quality of performance was rated on the basis of the standard [root mean square] error of tracking. The experiments were conducted during exposure to accelerations of up to 9 units directed at an angle of  $35^\circ$  in relation to the longitudinal axis of the human body. We recorded the accelerations, the EKG in the three leads of Neba, systolic arterial pressure in the vessels of the conchae, photoplethysmogram of the same region and minute respiratory volume. In all of the tests an anti-G suit was worn, and in order to enhance endurance of accelerations the subjects tensed the muscles of the prelum abdominale and lower extremities.

The study revealed that accelerations had a rather substantial effect on the quality of operator performance. With increase in accelerations there was an increase in tracking error, and this correlation was particularly noticeable with accelerations of over 6 units.

These changes in efficiency were correlated to a sufficient extent with the physiological parameters tested. Processing of physiological parameters and analysis

FOR OFFICIAL USE ONLY

of the subjects' accounts enabled us to single out the main factors limiting endurance of accelerations and efficiency. Visual disorders, general fatigue or pain in the hands were the most frequent cause of losing the light mark in tracking or determining the limit of endurance.

In this study, we determined the values of systolic arterial pressure in the head region (sensor on the earlobe), as well as amplitude of ear pulse, as a function of magnitude of accelerations. The experiments revealed that with accelerations of the order of 7 units the arterial pressure dropped to 30 mm Hg, while the amplitude of ear pulse dropped to 30% of the base levels, and as we know this is a sign of circulatory disturbances leading to visual disorders.

The pain in the arms [or hands] observed with accelerations of 9 units were apparently attributable to increased delivery of blood to the elbow and shoulder joint regions as a result of increased G forces.

Two types of chronotropic reactions of the heart to accelerations were demonstrated, and different dynamics of changes in minute respiratory volume corresponded to these types.

The obtained data enable us to determine the efficiency level with different magnitudes of  $+G_z$  accelerations.

FOR OFFICIAL USE ONLY

EXPERIMENTAL ESTIMATION OF BLOOD PRESSURE AND BLOOD IN VESSELS OF THE LOWER  
EXTREMITIES OF MAN EXPOSED TO LONGITUDINAL ACCELERATIONS AND WEARING A G SUIT

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 78-80

[Article by Ye. I. Sorokina]

[Text] The mechanism of protective action of G suits (GS) consists, first of all, of regulating delivery of blood to the lower half of the body during accelerations by creating the appropriate pressure curve there. The main objective of this work was to make a quantitative estimate of the changes in blood pressure and filling with blood of man's leg vessels with exposure to accelerations and use of various GS.

A curve of increment of arterial systolic pressure in the femoral artery--a linear function with mean gradient of increment of  $0.038 \text{ kgf/cm}^2/\text{unit acceleration}$ , was obtained in experiments on man exposed to longitudinal accelerations of 2-8 units. On the basis of these data and with due consideration of man's actual position in a force field, determination was made of the height of the hydrostatic column in relation to the level of measurement and position of the point where there was no change in blood pressure (hydrostatically neutral point). We then plotted the increment of hydrostatic pressure during accelerations for different regions of the lower half of the body.

For the quantitative evaluation of redistribution of blood as a result of the effects of acceleration and GS, determination was made (by the method of water plethysmometry in model experiments) of blood in the leg vessels as a function of changes in transmural pressure. Initial blood filling constituted a mean of  $62 \text{ cm}^3/\text{kg leg weight}$ . With increase in transmural pressure by 0.05, 0.10 and  $0.15 \text{ kgf/cm}^2$ , filling with blood increased by 20, 43 and 60%, respectively, of the base level. Filling decreased by 62, 71 and 80% with the use of external pressure on the lower limbs of 0.10, 0.15 and  $0.20 \text{ kgf/cm}^2$ , respectively.

These data, as well as the information about increment of hydrostatic blood pressure, were used as base material to estimate the dynamics of blood delivery to leg vessels during exposure to accelerations characterizing different types of GS. The estimates obtained were compared to the experimental data characterizing efficacy of GS according to the conventional criteria.

According to the estimates, GS that compensate in part the lower half of the body, i.e., which leave the feet, knees and upper thighs exposed, have the strongest

## FOR OFFICIAL USE ONLY

compensatory effect when pressure exceeding the systolic arterial level is created (so-called occlusion pressure). This is associated with expulsion of 750-810 cm<sup>3</sup> blood from the lower limbs. The traditional methods of comparing GS showed that the antigravity properties of occlusive pressure to the body are considerably higher than preocclusive.

In the regions of the lower half of the body that were not compensated by the GS, there could be deposition of a certain volume of blood during exposure to accelerations. Development of this process could be attributed to two factors--increased hydrostatic blood pressure as a result of accelerations and the constrictive effect of the proximal GS cuff. For example, estimates revealed that, under the influence of these two factors, there could be additional concentration of up to 250 cm<sup>3</sup> blood in the uncompensated feed and knee regions, with accelerations of 4 units. In experiments using 4 unit accelerations for 60 s, this figure constituted a mean of 205 cm<sup>3</sup>.

The maximum antigravity effect that it is possible to obtain by compressing the lower half of the body can be achieved by creating compensatory pressure over its entire surface, with a pressure gradient over its length that provides for shifting of blood from bottom to top and with absolute external pressure in excess of arterial systolic pressure in the lower extremities. In this case, the volume of blood forced into the upper half of the body constitutes about 1200 cm<sup>3</sup>. The preliminary data from comparative evaluation of the efficacy of GS providing partial compensation for the lower half of the body and creating compensatory pressure over its entire surface indicate that the second variant of GS has some advantages over the first one.

FOR OFFICIAL USE ONLY

# EFFECT OF $+G_x$ ACCELERATIONS ON CORTICOSTEROID EXCRETION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 80-81

[Article by L. I. Voronin, S. Yu. Yelizarov, R. K. Kiselev, N. V. Ulyatovskiy, V. P. Khmel'kov and I. P. Mikheyeva]

[Text] The endocrine system reacts to long-term exposure to accelerations. We conducted a study to determine individual resistance to  $+G_x$  accelerations on 12 essentially healthy subjects 25-30 years of age. We successively created a "plateau" of 4  $G_x$  accelerations for 60 s with a gradient of 0.1 G/s and a +8  $G_x$  "plateau" for 30 s with gradient of 0.2 G/s, the angle between the vector of acceleration and longitudinal axis of the trunk constituting 80°. There was a 5-7 min interval between exposure to 4 and 8 G accelerations. The parameters of heart rate served as the main criterion of resistance of  $+G_x$  accelerations. We assayed corticosteroids in urine by the method of thin-layer chromatography on silica gel before and after rotation (K. V. Druzhinina, 1965), with densitometric determination of cortisol, cortisone, corticosterone, 11-deoxycortisol and their tetrahydro forms. The steroid spectrum was studied in batches of urine collected for 2-3 h the day before exposure to accelerations and 1 h after. This interval after exposure was chosen with consideration of the period for elimination of 50% of the corticosteroids (Saffer et al., 1966). To compare the obtained results, we calculated the rate of corticosteroid excretion in  $\mu\text{g/h}$ .

As compared to the values we obtained at relative rest, mean hourly excretion of tetrahydro derivatives was 1.4-1.8 times greater, that of cortisol, cortisone and corticosterone was 1.6-2.4 times greater. These differences are apparently attributable to emotional stress, since the subjects wanted to get a good rating for resistance to accelerations. All subjects with a good rating of resistance were divided into two groups after exposure, according to changes in the corticosteroid spectrum of urine. The first group consisted of 10 people who presented a uniform increase in all tested steroid fractions by 1.2-1.8 times, without appreciable change in proportion of each, as compared to the background studies. The second group consisted of two people, one of whom presented 11-deoxycortisol in the batch of urine collected 1 h after exposure constituting 62% of the tetrahydrocortisone level in the same specimen. The second subject's chromatogram after exposure distinctly demonstrated 11-deoxycorticosterone. In all the other subjects, 11-deoxycortisol and 11-deoxycorticosterone were present in the specimens in the form of traces, and they were not assayed quantitatively.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Thus, in some subjects the above accelerations could have been the cause of marked change in corticosteroid metabolism. Relatively brief exposure to accelerations did not enable us to assess the prognostic significance of the changes observed in the second group. However, in our previous studies (L. I. Voronin, 1977), similar changes with longer exposure to accelerations were associated with a decrease in resistance to them, and they were interpreted as adrenocortical dysfunction.

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

EXPERIMENTAL THEORETICAL SUBSTANTIATION OF AN IN VIVO METHOD OF EVALUATING THE  
DYNAMIC STRENGTH OF THE HUMAN SPINE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 81-83

[Article by G. P. Mirolyubov, V. A. Elivanov, G. P. Stupakov and A. P. Kozlovskiy]

[Text] In flight, in case of accident and a number of other situations, the human body is submitted to the effects of impact accelerations, endurance of which is often determined by the strength of the spine. Since the strength of the spine differs significantly in different individuals, it is understandable that there is interest in the possibility of determining it in vivo.

For this purpose, a study was made here of the possibility of using the method of direct photon absorbiometry of the calcaneus, for which purpose we examined the relationship between dynamic strength of the spine with a longitudinal impact to density of the structure of the vertebral bodies and calcaneus, to the weight and age of people. To increase the reliability of the results, we determined the static strength of one vertebra ( $T_{10}$ ) and its relationship to structural density of the body of this vertebra and the calcaneus.

Dynamic strength of the spine was determined with experimental simulation of a load on the most frequently injured part of the human body ( $T_{11}$ - $L_3$  segment). The segments were extracted from the cadavers of men who had died at the age of 18 to 50 years of causes that did not affect the spine; they were submitted to a load corresponding to the weight of the part of the body above them and to longitudinal impact accelerations for 0.06-0.08 s on an impact tester. At the same time, we extracted  $T_{10}$ , which was used for static tests, and the calcaneus. The density of vertebral bodies and the calcaneus was evaluated on the basis of volumetric mineral content (mineralization) by the direct method (ashing), while the calcaneus was additionally submitted to direct photon absorptiometry using the Bone Scanner (Sweden) instrument.

Occurrence of dynamic lesions to the segments was determined by the strength of the body of  $T_{12}$ , which was used for analysis as being typical of the strength of the spine as a whole.

Analysis revealed the following:

Overall dynamic strength ( $P$ , kgf) and the range of dynamic strength ( $\sigma$ /kgf/cm) of the spine are determined essentially by mineralization of the vertebral bodies

FOR OFFICIAL USE ONLY

( $r_p = 0.884$ ,  $P < 0.001$ ;  $r_G = 0.912$ ,  $P < 0.001$ ). There was a mild link between strength of the spine and age ( $r_G = -0.448$ ;  $P < 0.05$ ), which is attributable to the slight decrease in mineralization of vertebral bodies after the age of 35 years. We failed to demonstrate a relationship between strength characteristics of the spine and body weight.

Mineralization of the calcaneus showed a correlation with mineralization of vertebral bodies ( $r = 0.729$ ,  $P < 0.01$ ), and as a result also with their range of dynamic and static strength ( $r = 0.636$ ,  $P < 0.05$  and  $r = 0.833$ ,  $P < 0.001$ , respectively).

A correlation was demonstrated between level of mineralization of the calcaneus determined by the direct and indirect (direct photon absorptiometry) methods, which is indicative of the prospects of developing the latter for in vivo evaluation of the strength of the human spine.

FOR OFFICIAL USE ONLY

ENDURANCE OF ACCELERATIONS DURING PERIODS OF CALM AND INCREASED SOLAR ACTIVITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 83-84

[Article by P. M. Suvorov, Yu. I. Bykova and K. A. Sidorova]

[Text] As early as the 1930's, the hypothesis had been expounded concerning the possibility of an adverse effect of increased solar activity on organisms and the plant kingdom. Some authors (A. I. Osipov, V. P. Desyatov, 1971; B. M. Bogolyubov, 1978) observed an increase in number of motor vehicle accidents, exacerbation of some diseases of the cardiovascular system during periods of magnetic storms, which could have been due to the drastic decrease in bioenergetic activity of the brain (N. Il'inskaya, 1978).

At the same time, several researchers (G. N. Kassil', 1978) believe that only individuals with latent functional disturbances, at a stage of illness when the mechanisms of regulating homeostasis are impaired, are hypersensitive to geomagnetic perturbances.

Our objective was to study endurance of accelerations ( $+G_z$ ) of flight personnel during years of calm (1963-1965) and increased solar activity (1968-1970).

The studies were conducted with a centrifuge in the mornings, using the methods adopted for medical certification of flight personnel (P. M. Suvorov, 1969).

We examined 357 people--85 in good health, 110 with vegetovascular instability (VVI) and 162 with neurocirculatory dystonia and essential hypertension, grade I (NCDH)--during the years of a calm sun (Wolf number 10-28).

During the years of increased solar activity (Wolf number 106-148), we examined the endurance of accelerations in 464 people, 167 of whom were in good health, 178 with VVI and 119 with NCDH. In view of the possibility of differences in endurance of accelerations as a function of age (P. M. Suvorov, 1968), all of the subjects were divided into two age groups: 20-35 years and 36-50 years, for which comparisons were made of endurance of corresponding nosological groups. The obtained data were processed by methods of variational statistics.

The results of these studies revealed that increased solar activity had no effect on endurance of accelerations in all three nosological groups studied. For

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

- example, while diminished resistance to accelerations was encountered in  $15.1 \pm 3.7\%$  of the subjects with VVI 20-35 years of age in 1963-1965; this was found in  $15.2 \pm 3.4\%$  in 1968-1970. The difference is statistically unreliable ( $t = 0.02$ ).

Thus, the encountered changes in solar activity had no appreciable effect on resistance to accelerations. Evidently, the presence of mechanisms for self-regulation of homeostasis, which were acquired in the course of evolution, enable essentially healthy individuals to adjust quite reliably to increased solar activity.

-

-

-

-

-

FOR OFFICIAL USE ONLY

EFFECT OF INFLATING G SUIT ON SOME PARAMETERS OF HUMAN HEMODYNAMICS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 84-86

[Article by L. I. Letkova and K. I. Murakhovskiy]

[Text] Studies of hemodynamic changes associated with compression of the lower half of the human body are of some interest with regard to evaluation of the compensatory properties of antigravity gear under laboratory conditions.

We studied changes in parameters of the cardiovascular system with creation of pressure in the chambers [tubes] of a regulation G suit. The subjects were seated in a mockup of an aircraft seat. Experiments were conducted on the ground, without the use of accelerations. After examining the base state of the cardiovascular system, excess pressure of 0.3 kgf/cm<sup>2</sup> was created in the suit within 2-3 s. Exposure time was limited to 9 minutes. We recorded the following parameters during the background examination and experiment: heart rate (HR), arterial pressure (AP), radiocardiogram (RCG) and rheoplethysmogram (RPG) of the chest. We calculated minute and stroke volumes (MV and SV), pulmonary blood volume (PBV), total mean circulation time, pulmonary circulation time and circulating blood volume (CBV) from the results of radioisotope studies (we used <sup>131</sup>I, albumin). We evaluated the dynamics of stroke volume throughout the experiment on the basis of the rheoplethysmogram, and we also calculated the work of the heart and total peripheral resistance (TPR).<sup>\*</sup> A total of 19 experiments were conducted on healthy men 18 to 40 years of age.

The results of this study revealed that the most marked and statistically reliable changes in MV and SV were noted in the first 10-20 s after creating pressure in the suit (SV increased by 20 ml, MV by 892 ml). Pulse rate remained virtually unchanged at this time. Arterial pressure rose somewhat. TPR diminished (by 41 dyne·s/cm<sup>5</sup>), while work of the heart increased (by 1.8 kg-m/min). Continued testing was associated with gradual normalization of SV and MV. Pulse rate remained at the base level. AP remained elevated, TPR increased constantly, and work of the heart decreased somewhat.

---

<sup>\*</sup>The measurements of cardiac output by means of radiocardiography and tetrapolar rheography for periods of simultaneous recording were analyzed by comparing sets with pair-related variants. It was found that the differences between them were insignificant for a probability level of 0.99.

FOR OFFICIAL USE ONLY

In the third minute of the test (time of the radioisotope examination) there was a statistically reliable decrease in CBV and total blood circulating time. The pulmonary blood volume and pulmonary circulation time increased statistically during the same period.

Upon removal of compressing pressure, the HR, MV and SV increased, as compared to the last minute of the test (HR by 25/min, MV by 3351 ml, SV by 12 ml). Both systolic and diastolic arterial pressure dropped by 26 mm Hg. TPR diminished drastically, by 561 dyne·s/cm<sup>5</sup>, and work of the heart increased by 0.7 kg-m/min.

By the 10th min after the test, we observed virtually complete restoration of the parameters of the cardiovascular system that we studied.

Thus, the greatest hemodynamic changes were observed in the first 10-20 s after creating and removing compressive pressure. Exposure to constant pressure was associated with gradual normalization of the main hemodynamic parameters, i.e., under "static" experimental conditions, the G suit did not cause a stable increase in SV and MV.

FOR OFFICIAL USE ONLY

OPTIMUM RESPIRATION DURING LONG-TERM EXPOSURE TO TRANSVERSE ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' 1 in Russian 1979 (signed to press 23 Apr 79) pp 86-87

[Article by G. A. Golov and Ye. P. Tikhomirov]

[Text] As we know, the limited endurance of long-term transverse accelerations is related chiefly to impairment of oxygen balance of the organism. Numerous studies have shown that there is rapid decrease in arterial oxygenation under such conditions. But there is no description in the literature of the influence on this process of deliberate pulmonary hyperventilation.

This study was pursued for the following purposes: 1) to determine the possibility of voluntary ventilation with accelerations of 4-12 units in the "chest-back" direction at an angle of 78°; 2) to examine the effectiveness of different types of respiration for the same range of accelerations.

It has been established that, during exposure to accelerations, man is capable of voluntary regulation of the nature of respiration and magnitude of pulmonary ventilation over a wide range without any special prior training. The ability to stop breathing (for 20-30 s at 10-12 units) is particularly remarkable.

The effectiveness of different levels of ventilation was tested in three series of experiments: a control with voluntary respiration, with hyperventilation and with hypoventilation.

With accelerations of 4-8 units, oxygenation was higher in the experiments with higher ventilation. At 10-12 units, oxygenation level was not correlated with level of ventilation.

The oxygen debit with accelerations of 4 units was higher in the experiments with hypoventilation than with hyperventilation. The correlation changed with accelerations of 10-12 units: oxygen debt was higher after hyperventilation.

Breath-holding at such levels of accelerations did not worsen endurance or increase oxygen debt.

Thus, it can be considered advisable to have moderate hyperventilation with accelerations of up to 8 units. With higher accelerations it is better to decrease the ventilatory function of the lungs.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

CLINICOPHYSIOLOGICAL STUDIES, AND THERAPEUTIC-PREVENTIVE MEASURES

MAIN ASPECTS OF THE REHABILITATION PROBLEM IN SPACE MEDICINE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 91-92

[Article by T. N. Krupina, B. M. Fedorov, V. T. Olefirenko, I. P. Lebedeva, S. G. Voronina, A. Ya. Tizul, E. I. Matsnev and N. I. Tsyganova]

[Text] The importance of continued work on rehabilitation problems is due to the increasing duration of space flights, in the presence of marked individual reactions of man. In the system of rehabilitation measures, attention is focused chiefly on the search for optimum rehabilitation measures to aid in processes of readaptation, normalization of altered vital functions, regulatory system and the musculoskeletal system.

Complex studies have been conducted on the ground, including the use of antiorthostatic hypokinesia for 6 months, in order to elaborate rehabilitation measures. In the last few years, it was learned that several complex rehabilitation measures, including contrast baths combined with therapeutic exercise, use of some pharmacological and physiotherapeutic factors that normalize vital systems of the body, are highly effective. The importance of resort factors in the system of rehabilitation measures is increasing.

At the same time, in developing rehabilitation measures it is of paramount importance to assess their efficacy in the most adequate tests. More recently, it was shown that the different systems of the body do not recover simultaneously after termination of exposure to space flight factors. For example, there is relatively late recovery of the microcirculatory system, so that the parameters of this system are very significant. The main future direction of studies of this problem is determined by the desirability of individualizing rehabilitation measures that would restore fitness as soon as possible after completing a flight.

The system of pathogenetically substantiated rehabilitation measures is based on principles of consistency and continuity. The first stage of rehabilitation is mainly a conservative one and the next ones are conditioning. The individual approach to optimum rehabilitation is based on comprehensive clinical evaluation of an individual's condition with special consideration of the severity of stress reactions, changes in the nervous and circulatory systems. The systems of rehabilitation measures developed to date, which include balneological procedures, kinesiohydrotherapy and therapeutic physical culture, are highly effective.

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

REHABILITATION AND THERAPEUTIC MEASURES FOLLOWING 140-DAY SPACE FLIGHT

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 92-93

[Article by O. G. Gazenko, A. V. Beregovkin, V. V. Bogomolov, S. G. Voronina, A. D. Yegorov, V. V. Kalinichenko, T. N. Krupina, I. M. Reznikov, G. D. Syrykh, A. Ya. Tizul, V. A. Tkachenko and L. M. Filatova]

[Text] After completion of a 140-day space flight, cosmonauts presented signs of general fatigue and asthenization, deconditioning of the body for orthostatic and physical perturbances, the syndrome of residual signs of redistribution of blood, statokinetic disorders, weight loss and atrophy of muscles of the lower limbs, moderate anemic syndrome with signs of microcytosis, change in fluid-electrolyte balance with a tendency to retain fluid, diminished immunoreactivity and dysbacteriosis. All these signs were moderate and, on the whole, were considerably less marked than after a 96-day space flight.

To alleviate and accelerate the readaptation process, sets of rehabilitation and therapeutic measures (RTM) were instituted from the first days, first at the spaceport (12 days, first stage) then at a sanatorium (moderate altitude, 28 days, second stage). The following RTM were performed at the first stage: regulated motor activity, remedial therapeutic massage of muscles, therapeutic physical culture and graded [measured] walking, hydrotherapy and thermotherapy, and psychoemotional measures.

For the first 2 days the regimen was conservative, on the 3d-8th it was conservatively conditioning and then conditioning, with inclusion of elements of brief running, and the curves of the exercise loads presented 1, 2 and 3 peaks, corresponding to these regimens of RTM. The amount and intensity of exercise increased gradually, and by the end of the first stage the graded walking amounted to 9-10 km per day. The moderate pain in muscles and ligaments that appeared upon walking and exercising was not a hindrance to these activities, and as a rule it was eliminated by massage and heat treatment. After the first stage of RTM, the condition of the crew improved significantly; however, signs of asthenization and diminished tone of some muscle groups persisted. The velocity and strength properties of muscles and general physical fitness were not yet fully restored. Further RTM were administered at moderate altitude, with the use of physical and balneological treatment. At the start of the second stage, the condition of the cosmonauts was described as showing residual signs of asthenization and vegetovascular dysfunction.

FOR OFFICIAL USE ONLY

The general program of RTM at the second stage consisted of the following: conservatively conditioning for the first 3 days (acclimatization), then conditioning regimen; terrenkur [?]; hand massage with emphasis on antigravity muscles; therapeutic exercise and swimming in a pool; sauna combined with relaxing massage, excursions, Narzan [mineral water] baths and others.

By the end of the second stage, the cosmonauts' general condition was virtually the same as before the flight, although some parameters had not yet been fully restored.

FOR OFFICIAL USE ONLY

PHARMACOLOGICAL STIMULATORS OF PHYSICAL FITNESS IN SPACE MEDICINE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 93-95

[Article by V. S. Shashkov, N. V. Gordeycheva and N. G. Lakota]

[Text] The choice of drugs to preserve and enhance fitness [or efficiency] is directly related to the distinctions of the state of the body and work program at different stages of a space flight. The prescription of agents not only requires serious physiological validation, but must be specific for different cases and individualized. Moreover, evaluation of the effects on fitness must be reinforced by methods that are adequate to the expected effect and proper analysis of data.

The practice of space flights compels us to pay special attention to general tonics: agents that prevent deconditioning of the cardiovascular system and metabolic disturbances, as well as agents that eliminate emotional tension.

In this work, we describe methods of assessing the effect of stimulating physical fitness in the case of a usual regimen of motor activity, hypokinesia and weightlessness.

The following drugs and combinations thereof were tested with regard to their effect on man's physical fitness: phenamine, methamphetamine, ephedrine, strychnine, sydnocarb, bimetil, glutamic acid, panangin, nerobol, saparal, Eleuterococcus, Lagochilus inebrians, potassium orotate, anaprilin, phosphrene and undevit.

The distinctions of the stimulating effects of different agents and substances were demonstrated by means of a rank rating, developed on the basis of experimental and estimated parameters of the system of external respiration and cardiovascular system during functional tests with graded exercise. Several substances and mixtures were recommended for practical use in space flight:

1. Lagochilus inebrians or Eleuterococcus, as agents that aid in adaptation and maintain fitness (the former has a sedative effect).
2. Glutamic acid; panangin or panagin with potassium orotate; glutamic acid, panagin, saparal, as tonic agents to prepare the body or cardiovascular system in particular for heavy physical work.
3. Ephedrine and strychnine, in the form of a short course for immediate enhancement of fitness.

FOR OFFICIAL USE ONLY

Analysis of the distinctive features in the action of the tested agents and combinations thereof enabled us to recommend them as stimulators of physical fitness at different stages of a space flight, when taken once or in long or short courses: during the period of preparations for a flight, during a long-term flight, in the prelanding period and in the recovery period after a flight, as well as for immediate [emergency] increase in fitness. Of special value are prescriptions that include concurrent and successive intake of general tonics and agents that have a specific effect on different systems of the body.

FOR OFFICIAL USE ONLY

AUTOGENIC CORRECTION OF COSMONAUT'S CONDITION IN FLIGHT

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 95-96

[Article by G. T. Beregovoy, L. P. Grimak, Yu. F. Isaulov, G. M. Kolesnikov, L. S. Khachat'ur'yants and Ye. V. Khrunov]

[Text] Analysis of the performance of cosmonauts in flight, made in both the Soviet Union and the United States, shows that, in some cases, the crews develop diverse functional disturbances related to space factors. In such cases, use of drugs and physical means for correction of these states does not always yield the desired result, since the pathogenesis of the functional disturbances is not quite clear in many instances, and it is difficult to diagnose them early enough.

With the increase in duration of space flights, the importance of this problem is also increasing, since there is a greater probability of occurrence of these changes in the cosmonauts at a time when they are virtually unable to submit to the direct care of medical specialists and psychologists.

For this reason, the problem of operational [ongoing] correction of fitness and interpersonal relations among crews during the flight period requires an immediate solution, in both its theoretical and practical aspects.

This paper submits experimental data on solving the problem of increasing the reliability and efficiency of manned space flights by using autogenic correction of mental states of cosmonauts during the flight.

Without touching on the purely medical aspects of this question, the report contains data on experimental investigation of the efficacy of autogenic training (AT) with simulation of space flights varying in complexity, including simulation of irregular (emergency) situations. It was shown that autogenic submersion [relaxation, concentration?] for 15 min, in accordance with a previously learned special training program, elicited a marked activating effect on operator efficiency, which persisted for 5-6 hours, even when this was preceded by 2 days of continuous work.

In addition, the paper discusses the possibilities of AT as a method to curb the adverse effects of different space flight factors (weightlessness, partial sensory deprivation, etc.), as well as to correct some of the developing functional disturbances. There are also data on experimental studies of the AT method as a means of preserving flight skills when there are prolonged forced interruptions of flight work.

FOR OFFICIAL USE ONLY

COSMONAUT CARE IN ORBIT: EXPERIENCE AND PROBLEMS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 96-97

[Article by V. I. Myasnikov, O. P. Kozerenko, A. Ya. Tizul and F. N. Uskov]

[Text] This paper is based on data obtained in the course of "field" tests of the Salyut-6--Soyuz-29-31 orbital complex. Data gleaned from other flight experiments are also discussed.

The thesis is developed concerning a new, modern form of practical work with crews--psychological care. Care refers to a developed system of measures called upon to assure the psychological reliability of cosmonauts during long-term flights. An entire set of problems, as well as some promising forms of work, must be discussed in connection with the advanced thesis.

Some results of organizational work are summed up in the category of expert diagnostic problems. Here, functional diagnostics, which is the result of close collaboration between physicians--psychoneurologists and medical psychologists, is viewed as a certain achievement. Special attention is given to a group of methodological questions. In particular, new possibilities are explored with regard to monitoring formation of symptoms (analysis of rhythmic characteristics); the informativeness of quantitative methods (estimation of verbal activity and verbal productivity, measurement of index of verbal participation and others) is discussed. The prospects of direct examination of expressive functions are discussed: isolation in received reports of verbal effects on the user [subject?], factors reflecting the speaker's own emotional state, etc. Several practical considerations are advanced in favor of two-way television communication with the craft. The expert diagnostic part ends with discussion of the concept of "daily mild malaise" as a certain initial functional background in the evaluations made.

With regard to other types of measures, some aspects of supportive, psychocorrective and rehabilitation work are discussed. This includes questions of optimum work and rest schedules with the possibility of operational interventions in the work cyclogram, measures to increase motivation for work and others. The regulatory factors are based on the principle of communication in the "subject-environment" system: communication in which the subject is neither alienated nor strongly dependent on his environment is considered psychologically comfortable. Within the context of regulation of such communication, there is discussion of the problem of optimizing the flow of information.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

The immediate plans are referable to questions of psychohygienic work with crews at the preparatory stages and in flight; new forms of recreation for crews (use of so-called functional music) and others are discussed.

In conclusion, it is stated that it is imperative to constantly refine the ways and means of working with crews, to create an effective system of care, not only for cosmonauts but personnel in the ground complex.

FOR OFFICIAL USE ONLY

ADVERSE REACTIONS IN THE ACUTE PERIOD OF ADAPTATION TO WEIGHTLESSNESS, AND THE PROBLEM OF PREVENTION THEREOF

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZNYAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 97-99

[Article by V. G. Voloshin, V. I. Stepantsov, V. S. Panchenko, V. A. Karpusheva and B. F. Asyamolov]

[Text] The first week in orbit is associated with the syndrome of acute adaptation to weightlessness, which has elements of intracranial hypertension and hypervolemia of thoracic organs. The increasingly complicated flight tasks make it imperative to develop means of alleviating it. This could be achieved by adequate preflight conditioning of compensatory mechanisms and inflight measures aimed at the circulating blood volume, hydration, level of blood in the head and chest.

A regimen of preflight conditioning was developed, which includes sleeping in antiorthostatic (head down) position (AO) and means of periodically shifting blood in a cranial direction. Use of AO with an angle of 30° reduced pulsed filling of the head (PFH) by 22%, lungs (Vc) by 11%, as compared to the control; there was significant improvement of endurance of AO.

LBNP [lower body negative pressure] (20-50 mm Hg in steps) in a 30° AO model was studied in the case of an already developed syndrome. In most subjects, the burdensome symptoms were removed after 5 min of LBNP of 20-30 mm Hg. PFH constituted 94% and Vc 81%. LBNP of 40 and 50 mm Hg lowered PFH to 62 and 51%, respectively, and Vc to 75 and 64%. The REG [rheoencephalogram] took on the form corresponding to orthostatic position.

We tested the efficacy of occlusion of the limbs with brief (30° AO) and prolonged (4 h, 15° AO) models of weightlessness. Occlusion of the four extremities in 30° AO ( $P_{occ} = 70$  mm Hg) lowered PFH from 165% to 98%, Vc from 140% to 104% of their levels in horizontal position, and eliminated all symptoms of the syndrome. The sensation of a smaller tilt angle appeared with the eyes closed, the REG took on a normal form.

With 15° AO, periodic occlusion of only the lower limbs with staggering of pressure from 30 to 60 mm Hg made it possible to hold PFH at 97-80% for a long time; Vc dropped by 20% and all unpleasant symptoms disappeared; the form of the REG was close to normal, while the position was perceived as horizontal when the eyes were closed.



FOR OFFICIAL USE ONLY

Use of three cycles of occlusion, each lasting 35 min, did not elicit appreciable change in elasticity of the crural veins.

Although both modes of occlusion normalized intracranial and pulmonary hemodynamics, we prefer the second one. It is very simple; it can be used for a long time, and it is convenient during operator work.

The experimental data confirmed the validity of the selected approaches for the prevention of the syndrome of acute adaptation to weightlessness.

FOR OFFICIAL USE ONLY

USE OF NEGATIVE PRESSURE FOR DIAGNOSIS AND PREVENTION OF CIRCULATORY DISORDERS DURING SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 99-100

[Article by B. S. Katkovskiy, Yu. D. Pometov, A. A. Savilov, A. A. Bobrov, V. A. Andretsov and V. S. Georgiyevskiy]

[Text] At the present time, one generally uses negative pressure applied to the lower half of man's body (LBNP) in space medicine practice for detection and prevention of cardiovascular disorders. Since LBNP can be used in weightlessness or simulation thereof to reproduce the distribution of blood inherent in man when standing erect, there are three possibilities for using it: a) to assess the functional state of man's cardiovascular system; b) as a means of conditioning the circulatory system at the last stage of a flight; c) as a means of curbing hemodynamic disturbances in the "acute" period of adaptation to weightlessness.

A test with LBNP, with stepped lowering of pressure in the vacuum from -25 to -50 mm Hg, was used in experiments involving simulation of weightlessness by means of prolonged (up to 182 days) stays in antiorthostatic [head end of bed tilted down] position (-4°).

Comparability of experimental data to the results of examining cosmonauts was assured by the identical levels and duration of LBNP at the first stage of the test. It was determined that there was relatively less worsening of the subjects' reactions to the test with LBNP when physical exercise, conditioning to LBNP and fluid-salt supplements were used as preventive measures.

A comparison of various modes of using LBNP in training to alleviate the readaptation period following hypokinesia revealed that a 2-h training regimen of LBNP (1 h a day for the last 2 days) was less effective than 9-h training (1-2 h/day for the last 5 days). The first regimen was found to be preferable, and it was recommended for use at the final stage of long-term space flights.

Three series of studies were conducted to determine whether disorders occurring in the "acute" period of adaptation to weightlessness could be prevented; in each series 8-10 subjects remained in antiorthostatic position (-22°) for 8 h. It was demonstrated that LBNP (first series) or local negative pressure to the legs (second series) under such conditions eliminated or diminished substantially the adverse phenomena observed in the control group (third series) of subjects.

**FOR OFFICIAL USE ONLY**

The experimental studies and comparison thereof to the results of examining cosmonauts graphically demonstrated the potential of all three directions of use of negative pressure in space medicine.

FOR OFFICIAL USE ONLY

ELECTRONEUROLEPSY (ELECTROANALGESIA) AS A METHOD OF PREVENTING AND TREATING  
FUNCTIONAL DISORDERS IN COSMONAUTS DURING THE READAPTATION PERIOD

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 100-102

[Article by L. S. Persianinov (deceased), I. P. Neumyvakin, S. N. Dizna, N. N.  
Rasstrigin, G. D. Syrykh, A. K. Yurchenko, L. G. Polevoy and V. A. Mikhaylov]

[Text] Weightlessness is one of the main factors causing somatic and autonomic  
disorders in cosmonauts during flights.

The search for and development of methods to prevent and treat them is still a  
pressing task for space medicine.

Clinicophysiological studies of the effects of electroneurolepsy on man, while  
submitted to antiorthostatic hypokinesia for 49 and 180 days, which were conducted  
at the Institute of Biomedical Problems, USSR Ministry of Health, together with  
the All-Union Scientific Research Institute of Obstetrics and Gynecology, USSR  
Ministry of Health, revealed that the neurotropic method of delivery of pulsed  
current combined with a constant galvanic component could serve as one of the  
effective means of preventing vegetovascular disorders, as well as one of the  
factors in faster readaptation. The studies were conducted on 38 operators 20-  
44 years of age. The sessions of electroneurolepsy were administered using the  
series produced Electronarcon-1 unit and a portable PElena unit for electro-  
analgesia, which we developed.

Square-wave pulsed current was delivered at a frequency of 400-1000 Hz, pulses  
lasting 0.2 to 0.4 ms, through electrodes applied to the forehead (split cathode)  
and neck under the mastoid process (split anode). Mean current ranged from  
0.2 to 0.5 mA, galvanic current constituted 20-30% thereof.

The condition if the subjects was assessed according to subjective data obtained  
with a questionnaire that we developed. Analysis was made of answers concerning  
well-being, sleep, appetite, presence or absence of pain, general discomfort.  
Objective criteria included parameters of hemodynamics, neurological status,  
and there was a psychological check.

The operators tolerated electroneurolepsy well, they usually fell asleep 5-7 min  
after the start of the treatment. After 40-50 min, the subjects felt energetic  
and rested. All of them had a positive attitude toward the sessions.

FOR OFFICIAL USE ONLY

At the first stage of antiorthostatic hypokinesia, it was found that operators submitted to electroneurolepsy tolerated the adaptation period better than the control group. They adjusted faster to the specified schedule for sleep, rest and mealtimes, which reverted to normal by the 4th-5th day. In the control group this occurred by the 9th-12th day.

In spite of the fact that there were no statistically reliable changes in arterial pressure, pulse and respiration rate, these data were indicative of better endurance of hypokinesia by operators in the experimental group. They presented less marked signs of physical discomfort, neurological and autonomic disorders, in particular the asthenoneurotic syndrome. The feeling of fatigue, tension, joint and muscle pain disappeared 10-12 days sooner than in the control group.

During the electroneurolepsy sessions, we observed that this treatment had a potentiating effect on pharmacological agents.

The staff of the Center for Cosmonaut Training used electroneurolepsy on cosmonauts in the period of readaptation following long-term space flights. Positive results were obtained, which conformed with the data obtained in the experiment.

FOR OFFICIAL USE ONLY

DISTINCTIVE FEATURES IN PLANNING PHYSICAL TRAINING DURING LONG-TERM SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 102-104

[Article by V. A. Tishler and V. I. Stepanov]

[Text] It is generally agreed that a number of disorders inherent in space flight may be averted or attenuated by means of active intervention in adaptive reactions. Specially organized and wisely planned physical training plays an important role in this.

With proper organization of physical exercise and methods of planning them, with due consideration of prevailing conditions, it is possible to selectively affect different pathogenetic elements of functional changes observed in weightlessness.

Consideration of several principles is important in planning the structure of exercise: principle of continuity (regularity) of exercise throughout the flight; principle of diversity of exercise and predominant direction of loads; principle of periodicity (repeated microcycles); principle of gradual increase in load per microcycle; principle of variability of loads and alternation of training exercises.

The specifics of conditions aboard space stations (limited size, heavy work program, limitations of simulators, low attraction of the cosmonaut to the surface of the "treadmill"--55 kg, etc.) make it necessary to adapt implementation of the above principles to such conditions. First of all, it must be borne in mind that deconditioning of the cardiovascular and other systems occurs quite rapidly in weightlessness (in 7-10 days), so that it is not desirable to start exercising later than after 4 days or to have lengthy breaks between them during the flight.

In view of the fact that there are polymorphic changes in chemistry and micro-structure of muscles, as well as a number of functional disturbances in different systems of the body, it is deemed mandatory, in planning the training microcycle, to make use of exercises varying in direction for manifestation of specific physical qualities (speed, strength, endurance and others). Because of the limited training equipment, the method of exercise is so planned as to develop different physical qualities in the same exerciser (for example, bicycle ergometer or treadmill). Consideration is given to the fact that physical conditioning can be effective in weightlessness only if the load intensity will be on the

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

level of average or above average work load (oxygen uptake of about 2 l/min) and energy expenditure will average 400-450 kcal/h. The physiological equivalent of such exercise would be a pulse rate of 140-160/min.

An important distinction of working out in weightlessness is the use of purposefully inertial-impact factors directed over the "head-legs" vector. This (walking, running, jumping) induces back and forth displacement of body fluids and, consequently, fluctuations of intravascular pressure, so that it is a substantial factor in causing adaptation of vessels (and hemodynamics) to orthostatic perturbances. Our data indicate that one must devote about 50% of the time to such conditioning.

Physical training in weightlessness should involve a sufficient load, and it must not be perceived solely as a regular element of the daily schedule. This is imperative in the life support system for crew members in the course of long-term flights.

Following this program during several missions aboard the Salyut station showed that with each successive mission the crew became increasingly convinced of the vital need of following the recommendations. The flight aboard Salyut-6, which lasted 140 days, revealed that achievement of 80-90% of the amount and intensity of training load resulted in a quite satisfactory condition of the cosmonauts, even better than in shorter missions where these parameters were substantially lower.

FOR OFFICIAL USE ONLY

PREVENTION OF PHYSICAL DECONDITIONING OF MAN BY MEANS OF REGULAR PHYSICAL EXERCISE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 104-105

[Article by B. S. Katkovskiy, G. V. Machinskiy, S. S. Kaniovskiy, Yu. D. Pometov and B. F. Demida]

[Text] A study was made of the efficacy of different methods of preventing physical deconditioning in people who had spent 182 days in strict bed rest (BR) with the body in antiorthostatic [head down] position, as it applies to long-term manned space flights. Preliminary studies revealed that a 2.5-h set of physical exercises (PE), corresponding to about 400 kcal/h, previously developed and used during long-term space flights was highly effective. However, in view of the fact that the cosmonauts have a heavy work load, performed in the interests of the national economy, and scientific experiments to do, it is of great practical interest to further refine PE directed primarily at saving time and energy expended on it.

For this purpose, 18 essentially healthy subjects were divided into 3 groups of 6 people in each. The first group of subjects performed a set of PE during BR that was close to the one recommended for long-term space flights (for 2.5 h on a 3+1 program, i.e., 3 days of exercise and one off) corresponding to about 350 kcal/h. The second group of subjects performed PE following a new "experimental" schedule for an average of 45 min, corresponding to about 165 kcal. The third group served as a control.

Physical fitness of the subjects was evaluated by means of the bicycle ergometer test with increase in steps of physical load before the start of BR, as well as on the 50th, 90th, 135th days of BR and on the first day of the recovery period (RP).

Analysis of the results of the bicycle ergometer tests revealed a substantial decline of physical fitness in the control group of subjects (third group). The most intensive decline was noted during the first half of the experiment (by 35% on the 50th day and by 47% by the 90th day). Thereafter, no appreciable change in fitness was noted.

Use of both exercise programs preserved physical fitness of most subjects at a close to base level. For example, in the group of subjects following the experimental training program, the maximum decline of physical fitness constituted a

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

mean of only 4.3% on the 135th day of BR, whereas in the group following the more intensive training program it even increased (5.6% above the initial level). Examination of fitness on the first day of the RP revealed that it increased in both groups to about the same extent, as compared to the base level (by 6.6 and 6.3% in the first and second groups, respectively).

Gas exchange changed insignificantly in the groups following the two different preventive regimens, whereas in the control group it diminished concurrently with change in fitness.

It was concluded that the principles and methods serving as the basis of the training programs used can be applied for development of the means of maintaining a high degree of physical fitness in individuals who spend much time in restricted living spaces without adequate muscular activity. At the same time, the results of these studies indicate that it is imperative to individualize physical training (with regard to intensity and amount), in accordance with the health status and level of physical conditioning of the person.

FOR OFFICIAL USE ONLY

THE PROBLEM OF ADAPTATION OF THE CIRCULATORY SYSTEM TO WEIGHTLESSNESS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 105-107

[Article by V. V. Kalinichenko, A. V. Beregovkin and A. F. Zhernavkov]

[Text] The difficulties that man is known to have in adapting to weightlessness puts the task to space medicine of alleviating and speeding up this process in order to preserve the functional reserves of the body and professional fitness of cosmonauts in flight. To achieve partial adaptation of the circulatory system to weightlessness under ground-based conditions, i.e., preadaptation, one can take advantage of the similarity of the main hemodynamic changes that occur in weightlessness and antiorthostatic [head down] position that simulates it.

Since the circus art and sports, as well as special experimental studies, showed that it is possible to increase endurance of an antiorthostatic load, it was logical to conclude that it is also possible to increase endurance of weightlessness by means of physical exercise with antiorthostatic loads. We have been studying this approach since 1970, in the course of preparing cosmonauts for space flights.

In all, 23 cosmonauts underwent special training, 3 of whom flew more than once. The cosmonauts reported that there was great similarity between the effect of weightlessness and antiorthostatic position. As a rule, there is an increase in resistance of the circulatory system to antiorthostatic loads, which reflects adaptation to weightlessness. The degree of adaptation to weightlessness varied on an individual basis, even after long-term space flights. The impression was gained that each person has his own specific potential level of adaptation to weightlessness, which he reaches during the first weeks of flight. The experience with special training shows that a significant part of this level can be reached on the ground. The process of adaptation is, so to speak, advanced, shifted under the more favorable conditions on earth. In the course of training under ground-based conditions, it is possible to adhere to the main principles of training, for which reason there is an increase in functional reserves and flexibility of the circulatory system. The principal routes and mechanisms of adaptation are set up and formed on the ground and they become complete in weightlessness. Special training alleviated and accelerated the process of adaptation to weightlessness; it was instrumental in preserving fitness and creating a favorable background for preventive physical exercise in flight.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

PROBLEMS OF REFINING GROUND-BASED COSMONAUT TRAINING

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 107-108

[Article by I. Ya. Yakovleva, M. M. Korotayev, A. F. Zavadovskiy, L. N. Kornilova, V. P. Baranova, Yu. A. Motorin, A. V. Borodin and I. A. Plyasova-Bakunina]

[Text] The successful fulfilment of space flight programs in our country is indicative of the validity of the system used for ground-based training of Soviet cosmonauts.

At the same time, medical studies and monitoring of the distinctions of individual reactions of cosmonauts in LKI [expansion unknown] revealed that the most marked adaptive reactions occurred in the first 7-10 days of flight, i.e., at the time of most intensive work of crew members. These reactions were due essentially to redistribution of fluids and blood to the upper half the body and impairment of functional organization of analyzers, i.e., a sensory conflict. In this regard, the system of ground-based training of crew members should be redirected in order to enhance the adaptive capabilities of the body with regard to the main factors of the first days of flight: redistribution of fluids in a cranial direction and sensory conflict.

These circumstances served as grounds to work on refinement of the principles applied to the approach to the system of ground-based cosmonaut training.

Studies were conducted in two directions: elaboration of some methodological procedures to condition the body to redistribution of fluids in a cranial direction; refinement of a model, search for informative tests and criteria to assess the conditioning effect on an experimental sensory conflict.

We used nocturnal sleep at a negative angle of  $-5^{\circ}$  and four different variants of orthostatic-antiorthostatic conditioning on a turntable as means of enhancing endurance of redistribution of blood to the upper part of the body. It was demonstrated that development of adaptive and adjustment reactions to antiorthostatic conditions is possible. This was indicated by the decreased pulsed delivery of blood to cerebral vessels in antiorthostatic position, decline of intranasal resistance and intraocular pressure, less change in gas exchange and fundus of the eye, as well as improved well-being and lesser rush of blood to the head.

According to the results of recording a wide set of physiological parameters, the tested set of models of sensory conflict (combination of balancing on an unstable

FOR OFFICIAL USE ONLY

- surface with optokinetic stimulation in the form of stripes at an angle of 45°) led to development of specific and nonspecific habituation, and it can be used as a conditioning stimulus. Informative criteria were established to assess the conditioning effect.

- Thus, the obtained experimental data warrant recommendation of the tested models for ground-based training of cosmonauts, as a means of enhancing adjustment and adaptation mechanisms of man with regard to the first stage of exposure to weightlessness.

FOR OFFICIAL USE ONLY

EFFECT OF BASE LEVEL OF PHYSICAL CONDITIONING ON ENDURANCE OF LIMITED MOTOR ACTIVITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 108-110

[Article by V. V. Vasil'yeva, L. N. Petrova, V. I. Korol'kov and Yu. V. Gordeyev]

[Text] There are rather contradictory data in the literature concerning the role of initial level of conditioning of the body in endurance of subsequent hypokinesia (V. P. Krotov, 1970; Klein et al., 1977; V. A. Shkurdoda, 1963).

The purpose of these studies was to determine the specific effect of regular exercise on endurance of subsequent hypokinesia. Experiments were conducted on rats. We studied their weight, morphological composition of peripheral blood, bactericidal activity of the integument, steroid levels in blood; we observed the dynamics of weight of adrenals and weight characteristics of the thymus and lymphatic system, and we determined the "altitude ceiling."

Hypokinesia was produced by keeping the animals in special cages that drastically limited movement for 10 days.

Restricted motor activity caused a 53-g decrease in body weight gain, as compared to the control group, with statistically reliable increase in weight of the adrenals, 3-fold increase in 11-oxycorticosteroid levels. Adrenocortical hyperfunction led to rapid involution of the thymus, the weight of which dropped by 65%, as compared to the control. There was also a reliable drop in weight of the spleen. There was no change in functional state of peripheral blood erythrocytes. Eosinophil content of blood was 60% of the control level in the experimental group. Bactericidal activity of the integument was negligibly diminished in experimental animals, as compared to the control.

Another group of animals underwent 30-day training with graded exercise. The animals ran on a treadmill for 20 min daily, with the "track" moving at 5 km/h. After conditioning for 1 month, the animals were put in hypokinetic cages.

The 30-day period of physical conditioning elicited negligible retardation of weight gain; there were no reliable changes in weight of the thymus, spleen or adrenals. Peripheral blood and bactericidal activity of the integument did not change. There was a reliable increase in "altitude ceiling."

FOR OFFICIAL USE ONLY

The 10 days of restricted movement, which followed physical training, led to a drop of body weight by an average of 41 g, as compared to the period of termination of physical condition, and by 74 g, as compared to the control group of animals. There was significant increase in weight of the adrenals and involution of the thymus. The eosinophil content dropped to one-third. Bactericidal activity of the integument was reliably diminished. The "altitude ceiling" was substantially lower, as compared to both the control and the group of rats whose movements were not restricted after the physical training. A comparison of the animals' endurance of hypokinesia revealed that the base functional state of the organism was very important with regard to endurance of extreme factors. In our studies, animals that were conditioned through exercise endured the restriction of motor activity more poorly.

These findings lead us to question the need for intensified physical conditioning of people and animals who will have to spend a long time under conditions of restricted motor activity.

FOR OFFICIAL USE ONLY

EFFICACY OF PREVENTIVE MEASURES DURING HYPOKINESIA, ACCORDING TO STABILOGRAPHIC DATA

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 111-113

[Article by A. R. Kotovskaya, L. N. Gavrilova, V. A. Tishler and R. R. Galle]

[Text] At the present time, various methods for preventing the adverse effects of weightlessness have been developed and experimentally validated.

It is known that hypokinesia is the conventional model of the effects of weightlessness. Models, in which hypokinesia is combined with antiorthostatic position (A. M. Genin, L. I. Kakurin, 1972, and others), are better suitable for experimental studies of the effects of weightlessness. We chose as such a model 182 days of antiorthostatic hypokinesia (AOH), with the head end of the bed tilted down to an angle of  $-4^\circ$ . Two groups of subjects, with 6 people in each, participated in these studies: the first was a control and the second experimental, with the use of a set of preventive measures, which included exercise for 2 h/day corresponding to 300-400 kcal/h, training with creation of negative pressure in the lower half of the body [LBNP], and scheduled intake of water and salts according to a special cyclogram.

We used the stabilographic method of studying equilibrium function to assess the effect on man of long-term AOH and the efficacy of the set of preventive measures. The ability to maintain equilibrium in a vertical position is an important integral indicator of man's general condition and fitness.

Stabilography (Ye. B. Babskiy, V. S. Gurfinkel's, 1952) was performed during hypokinesia, on the 4th, 14th, 30th, 50th, 90th, 134th and 183d days, with recording of fluctuations of the body's center of gravity in the frontal and sagittal planes.

The results of this study revealed that there was appreciable impairment of the capacity to maintain a vertical position during hypokinesia. Such disturbances progressed gradually. For the first 14 days of hypokinesia, the equilibrium disturbances were mild. A reliable elevation of stabilographic parameters was demonstrated on the 30th day. From that time on to the end of the period of hypokinesia there was a distinctive "plateau," when further statistically significant change in stabilographic parameters was not observed.

In the second group, as in the first, there were unreliable changes in stabilographic parameters for the first 14 days, as compared to background data. From

FOR OFFICIAL USE ONLY

the 30th to 50th days, they became more marked and statistically significant. On the 90th, 134th and 183d days no reliable differences from background data were demonstrable.

Analysis of the results of these studies enabled us to demonstrate phasic changes in equilibrium function during AOH: phase of build-up characterized by distinct elevation of stabilographic parameters. This phase lasted less than 30 days. The second one was a phase of relative stabilization, and its duration varied in the different groups: we demonstrated this phase in the first group for up to 182 days; in the second group the phase of stabilization was shorter than in the control group, covering the period from the 30th to 50th days, and from the 90th day to the end of hypokinesia there was a phase of normalization, when no reliable differences of stabilographic parameters from background data were recorded.

Thus, the results of our stabilographic study, which was conducted during 182 days of AOH, enabled us to demonstrate certain changes in equilibrium function and the possibility of preventing them with a set of measures, in which an important place was assigned to physical exercise.



FOR OFFICIAL USE ONLY

EXPERIMENTAL VALIDATION OF A SET OF PREVENTIVE MEASURES FOR LONG-TERM MANNED SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 113-115

[Article by L. I. Kakurin and V. M. Mikhaylov]

[Text] Some important scientific information has been gathered in the last few years, which indicates that the considerable increase in time man spends in weightlessness does not change essentially the order in which functional disorders develop and the physiological systems they involve.

It has become apparent that, like in the case of short-term flights, these changes are adaptive, mainly functional in nature, and to a lesser extent structural, so that there are no serious grounds as yet to qualify them as morbid.

The adaptation process is gradual. It presents several stages. A relatively stable functional level is reached 1-1.5 months after the start of a flight. At the same time, on the basis of existing data, we feel confident that the reserve capabilities of man are not sufficient to maintain the level of fitness that is required to fulfill the flight program, which is increasing in volume and complexity, and, what is also very important, to preserve activity of the crew in the first hours and days after returning to earth.

In long-term flights, the role of preventive measures, i.e., in our interpretation, the ways and means of preventing, attenuating or correcting undesirable functional changes, increases appreciably and is on a par, with regard to importance, with life support systems.

Preventive measures, which were deemed convenient for use during space flights, were tested in a ground-based experiment with simulation of the physiological effects of weightlessness. They differed in pathogenetic orientation. We refer to different types of physical conditioning, electrostimulation of muscles, application of negative pressure to the lower half of the body, intake of salt and fluid in excess of the usual intake level. The objective was to preserve the initial functional state (or close to it) of the main physiological systems of a subject who spent 6 months in antiorthostatic ( $-4.5^\circ$ ) position (with the head lower than the legs) with restriction of active muscular activity.

FOR OFFICIAL USE ONLY

In an experiment on 18 subjects (3 groups of 6 people) 31-40 years of age, a distinct beneficial effect was obtained in the individuals who used the set of measures and preventive methods similar to the set used aboard the Salyut-6 orbital station. For example, all six subjects in this group performed exercise on a bicycle ergometer, with intensity of 800 kg-m/min for 5 min, on the very first day after antiorthostatic hypokinesia. The same physiological reactions were observed as before the experiment. An analogue of this set of preventive measures elicited a high positive effect during the flights of cosmonauts Yu. V. Romanenko and G. M. Grechko (96-day mission), V. V. Kovalenko and A. S. Ivanchenkov (140 days).

A somewhat less marked, but distinct positive effect was observed when an abbreviated set of preventive measures, requiring half the expenditure of energy and conditioning time than the preceding one. In the control group of subjects (without preventive measures) we observed the hypokinetic syndrome inherent in such extreme conditions.

Further progress can be made in the problem of prevention when we gain deeper knowledge in the field of genesis of functional disorders and different levels of so-called homeostatic stability observed in man during space flights.

FOR OFFICIAL USE ONLY

PHARMACOTHERAPY USING NEW ACTOPROTECTIVE AGENTS FOR DISTURBANCES CAUSED BY  
LONG-TERM HYPOKINESIA

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) p 115

[Article by M. A. Polyakova]

[Text] The mechanism of action of new actoprotective agents--derivatives of  
thiobarbituric acid--for acute hypoxia of different genesis made it possible to  
use such agents in rats and rabbits during 30 days of hypokinesia.

The wide scope of functional and biochemical studies revealed drastic functional  
disturbances of the skeletomuscular system and metabolic processes. Thus, on  
the 15th day of the recovery period, control animals presented a 3.5-fold decrease  
in static-force and staticodynamic fitness, with drastic decrease in levels of  
creatine phosphate, ATPase and glycogen of muscles and the brain, with increase  
in concentration of lactic acid, sugar and cytochromoxidase in blood.

Preventive administration of actoprotective agents to experimental animals created  
conditions for adequate and sufficient synthesis and utilization of energy,  
stabilization of homeostasis, maintenance of physiological functions and bio-  
chemical processes, and elimination of the adverse effects of hypokinesia.

The obtained findings are indicative of the desirability of using actoprotective  
agents during the hypokinetic and recovery period to maintain physical fitness  
and resistance following long-term immobilization.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

THE PROBLEM OF ASSESSING DEGREE OF ADAPATION TO LONG-TERM SPACE FLIGHT CONDITIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' 1 in Russian 1979 (signed to press 23 Apr 79) pp 116-117

[Article by R. M. Bayevskiy, G. A. Nikulina, T. D. Semenova and I. G. Tazetdinov]

[Text] For the last few years we have witnessed the fulfilment of the ingenious predictions of K. E. Tsiolkovskiy about the planned conquest of space by man. The increase in duration of manned space flights to 3-5 months is broadening substantially our conceptions of the ability of the organism to adapt to weightlessness and further increase in time spent by man in space. At the same time, the need to return to earth's gravity advances, at the present stage, the task of maintaining the body's adaptive capacities at a rather high level, to assure relatively rapid readaptation without appreciable pathological manifestations.

Thus, the task of assessing the adaptive mechanisms and degree of adaptation to ambient conditions acquires substantial and practical importance for space medicine.

To perform this task, in addition to traditional clinicophysiological methods, we used aboard the Salyut-6 orbital station several new methods for the study and evaluation of strain on regulatory systems of the body. Mathematical analysis was made of heart rhythm, which enabled us to make a judgment about the state of the sympathetic and parasympathetic branches of the autonomic nervous system and activity of subcortical nerve centers on the basis of fluctuations in duration of cardiac intervals. We studied transitory processes of rhythm and force of cardiac contractions during exercise, which enabled us to assess the functional reserve and flexibility of regulatory mechanisms. We examined the mineral-secreting function of salivary glands, which contains information about the adrenosympathetic system. To evaluate the adaptive capacities of the organism, we analyzed the structure of the circadian rhythm of different physiological parameters. The method of dynamic electrocardiography turned out to be quite informative; it yielded information about the electrical activity of the heart over a 24-h period, including all work operations, sanitary-hygienic and housekeeping measures and sleep.

The obtained experimental data revealed that, in spite of the normal range of fluctuation of the main physiological functions, some degree of strain on regulatory mechanisms is observed in the course of a long-term space flight. Complex functional change in interaction of systems and organs is required to maintain a certain degree of adaptation to space flight conditions and preserve adequate functional capacities for readaptation to earth.

**FOR OFFICIAL USE ONLY**

One of the purposes of forecasting man's state in flight is the early detection of incipient adverse changes in the adaptation process, called upon to promptly define the scope and nature of preventive recommendations.

Thus, medical monitoring, forecasting and prevention are elements of the same system of medical support of modern, long-term space flights.

FOR OFFICIAL USE ONLY

SPECIAL BREATHING EXERCISES IN THE SYSTEM FOR CONDITIONING AGAINST THE ADVERSE FACTORS OF LONG-TERM SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 117-118

[Article by Yu. G. Perevertov and M. A. Mil'khiker]

[Text] Breathing exercises are offered to compensate for circulatory disturbances, involving graded inspiration and expiration while performing exercises consisting of calm inspiration lasting 2 pulse beats, breath holding in inspiration for 2 pulse beats, maximum expiration for 4 pulse beats and pause after expiration for 4 pulse beats. This means that one respiratory cycle corresponds to 12 pulse beats. Man takes 5-8 breaths per min (depending on the pulse rate of the subject). However, this does not elicit hypoxia, since a maximum amount of air is removed from the lungs, which is usually not involved in active respiration, because of the increased reserve expiratory volume.

We submitted to clinical observation 104 people of both sexes suffering from diverse neurological and cardiovascular diseases. In most cases, the "algorithmic respiration" that we proposed had a beneficial effect.

In our opinion, "algorithmic respiration" and the developed exercises could be used as an adjunct to the existing system of training people.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

PROBLEMS OF FORECASTING AND PREVENTING ALLERGIC COMPLICATIONS DURING LONG-TERM SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 118-119

[Article by I. V. Konstantinova, Yu. G. Nefedov, Ye. G. Antonova, V. I. Drozdova, G. P. Teplinskaya, Ye. N. Antropova, O. A. Guseva, V. I. Legen'kov, V. M. Mikhaylov and T. Yu. Norkina]

[Text] The nature of changes in immunological reactivity demonstrated after space flights enabled us to expound the hypothesis that there could be allergic complications under such conditions (I. V. Konstantinova, Yu. G. Nefedov et al., 1970). For this reason, the program of immunological examination of cosmonauts was enlarged with an allergological section.

The immunological system was submitted to comprehensive examination in 18 cosmonauts, many times before and after space flights lasting 2 to 140 days, as well as 55 subjects who participated in ground-based control experiments. The methods of examining the pool of thymus-dependent lymphocytes were used to determine appearance of specific T lymphocytes, which are effectors of hypersensitivity of the delayed type, their ability to produce humoral mediators--lymphokines (factor of inhibition of leukocyte migration), proportion between total population of T lymphocytes and subpopulations of T cells with receptors for the Fc fragment of immunoglobulins, on the one hand, and "active" T lymphocytes, on the other, functional activity of the T population (according to capacity for phytohemagglutination blast transformation and rate of RNA and DNA synthesis). Concurrently, we used clinical intracutaneous and application tests with a number of bacterial and chemical allergens.

Examination of peripheral blood lymphocytes of 4 out of the 18 cosmonauts revealed that a clone of cells sensitized to a specific antigen appeared after completing space flights of differing duration. In three cases this was a streptococcal antigen and in the fourth a chemical hapten (formaldehyde).

In 9 experiments using chambers, lasting 15 days to 4 months, with simulation on the ground of different factors inherent in space flights, none of the 37 subjects demonstrated appearance of sensitization to bacterial allergens.

Positive results were obtained in a clinical experiment with simulation of the effects of weightlessness (182 days of antiorthostatic hypokinesia). Sensitization appeared 1.5-3 months after the start of hypokinesia and persisted upon subsequent

FOR OFFICIAL USE ONLY

examinations of the subject (including the period after termination of the experiment). With increase in duration of the experiment, some subjects showed a gradual increase in spectrum of allergens that yielded a positive reaction. A change from monovalent to polyvalent sensitization was demonstrated both in the analysis of blood lymphocytes in vitro and in the intracutaneous tests.

In the experiment with antiorthostatic hypokinesia, a positive correlation was demonstrated between sensitization to staphylococcus and duration of furunculosis, which developed; myocardiodystrophy of the infectious-toxic type developed in one of the subjects with sensitization to streptococcus during the experiment.

The obtained results are interpreted as confirmation of regulation of immunological homeostasis in man by a clone of suppressor T lymphocytes. Analysis of the mechanisms of the demonstrated disturbances will be continued.

The results of these studies confirm the need for constant monitoring of the dynamics of immunological reactions of man during a prolonged period of exposure to weightlessness. The measures that are to be developed to normalize the immunity system should also prevent complications of an allergic nature during long-term space flights.



FOR OFFICIAL USE ONLY

EXISTENCE OF 'RESIDENT TYPE' CARRIERS OF STAPHYLOCOCCUS AUREUS AMONG COSMONAUTS BEFORE FLIGHTS, AND SOME MEASURES FOR PREVENTION OF DISEASE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) p 120

[Article by T. N. Nikolayeva]

[Text] Conditionally pathogenic microorganisms present a hazard during space flights, not only to the carrier but the entire crew. The existence of carriers of S. aureus is attributable, on the one hand, to the immunobiological properties of the macroorganism and, on the other hand, the nature of the microbial flora of the surface of the mucosa of the respiratory tract. In carriers of the "resident type," in whom S. aureus is constantly demonstrable in appreciable amounts... [sentence not completed in source].

For this reason it is necessary to detect carriers of S. aureus among cosmonauts preparing for long-term space flights and to institute preventive measures.

Studies of cosmonauts for demonstration of S. aureus carriers revealed that it is present in 79.4% of the individuals examined.

Investigation of the immunological status of carriers of the "resident type" revealed a decline of phagocytic index (Wright's index), lysozyme content of saliva, bactericidal activity of blood serum, as well as a tendency toward decrease in immunoglobulin A in saliva.

We proposed preventive administration of staphylococcal anatoxin [toxoid], primarily to carriers of the "resident type." Administration of this immunological agent just prior to flights led to increase in specific antistaphylococcal immunity and quantitative reduction and elimination of S. aureus from the upper respiratory tract. No S. aureus was demonstrable for the next 5 months of observation, including the flight period.

Thus, staphylococcal toxoid can be used to prevent diseases caused by S. aureus, as well as to treat carriers of the "resident type."

FOR OFFICIAL USE ONLY

SOME OF THE RESULTS OF THE INTERNATIONAL 'AUDIO' EXPERIMENT CONDUCTED IN FLIGHT ABOARD THE SALYUT-6 ORBITAL STATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) p 121

[Article by V. Prel' (GDR), I. I. Bryanov, M. V. Nefedova, I. Ya. Yakovleva and V. A. Kaptsov (USSR)]

[Text] There is a significant burden on the auditory analyzer during space flights, due to the continuous operation of fans, transformers and other elements of the life support system. Several cosmonauts have reported the irritating effect of radio signals.

Heretofore, no studies had been made of cosmonauts' hearing in flight. Investigation of the auditory system of cosmonauts in flight would not only broaden our conceptions of the phenomenology of man's reactions to space flight factors, but would be of practical value for development of recommendations to refine medical support of manned space missions.

The "Audio" experiment dealing with the state of hearing in flight was conducted aboard the Salyut-6 orbital station by an international crew consisting of V. Bykovskiy and S. Jaehn, on the basis of joint plans of specialists from the USSR and GDR.

Thresholds of air conduction for pure tones at frequencies of 500, 1000, 2000, 3000, 4000 and 6000 Hz were determined with a portable audiometer manufactured in GDR. The cosmonauts conducted these studies after a cycle of training 30, 5 and 3 days before the flight, twice (on the 3d day) during exposure to weightlessness and in the readaptation period.

The results of dynamic audiometry are discussed. According to the data from the background examination, there were individual distinctions in hearing thresholds inherent in individuals engaged in flight professions. During the flight, changes were recorded in hearing, mainly in the low-frequency range of the auditory field. For 1 day after the flight the changes in auditory sensitivity persisted, and this was indicative of marked signs of fatigue of the auditory analyzer.

The possible mechanisms of changes in the hearing of cosmonauts and recommendations based on this experiment are discussed.

FOR OFFICIAL USE ONLY

SYSTEM OF MEDICAL CARE FOR COSMONAUTS DURING FLIGHTS DIFFERING IN DURATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 122-123

[Article by I. P. Neumyvakin]

[Text] At the present time, it is unquestionable that cosmonauts may contract diseases during flight, and with increase in duration of flights the probability of diseases increases. The following may be contributory factors: diminished resistance, change in functional state of different organs and systems under the influence of space flight factors, etc. By extrapolation of data obtained from analysis of medical support of autonomous expeditions (underwater swimming, antarctic and arctic expeditions, etc.), as well as data from actual space flights, the possibility cannot be ruled out that cosmonauts will develop conditions and diseases that will require specialized medical care. Various emergency situations that are difficult to predict may be the preconditions for development of acute states; however, the probability thereof cannot be entirely ruled out.

In spite of the similarity of earth and space medicine, the distinctions of space flight conditions require a basically different approach to the solution of a number of problems of medical support for cosmonauts. The main distinction is the continuity of therapeutic and preventive measures at the preparatory stages, during flight and in the postflight period.

Implementation of a broad set of preventive measures in the preflight period (comprehensive physical training, disinfection measures, therapeutic and preventive surgical intervention) and during the flight not only enhance resistance to the space flight factors, but prevent development of a number of functional disorders and diseases among the crew.

In view of the foregoing, the system of rendering medical care to cosmonauts should be planned with due consideration of the following:

During relatively short-term space flights, medical care is rendered in the form of self-help and mutual help using the resources stowed on board.

During long-term orbital flights or flights to other planets, the crew must include a physician with rather broad medical training, particularly in the field of surgery and intensive care.

FOR OFFICIAL USE ONLY

There must be adequate medical supplies aboard a spacecraft to permit medical care of the most probable acute states, including the possibility of surgery.

In the absence of a physician on board during space flights, when it is impossible for a sick cosmonaut to return to earth without administering therapeutic measures, it is imperative to specially launch a spacecraft with a medical specialist.

Development of a system of rendering specialized medical care requires performance of a set of investigations. These studies should be directed toward finding and developing the ways and means of rendering specialized medical care.

FOR OFFICIAL USE ONLY

PATHOPHYSIOLOGICAL ASPECTS OF SURVIVAL OF CREWS OF FLYING VEHICLES AFTER EMERGENCY LANDINGS IN COLD REGIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICESKOY BIOLOGII I AVIAKOSMICESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 123-125

[Article by V. G. Volovich, O. K. Bychkov and A. Z. Mnatsikan'yan]

[Text] Survival and rescue of crews of flying vehicles after emergency landings is a complex process of interaction between the search-and-rescue personnel and victims. Determination of physiologically validated criteria of permissible time of independent existence of pilots or cosmonauts who have a small supply of water, food and extremely limited gear is of substantial importance to elaboration of the medical requirements with regard to search and rescue complexes and special means of protection and life support.

This problem can be solved only if there is thorough understanding of the distinctions of man's stress reactions to extreme environmental factors as a whole and knowledge about the critical states of the body, with which the functional changes could turn to pathological ones presenting a danger to health and life.

Studies were made of heat, energy, fluid-electrolyte metabolism and hemodynamics of subjects who had spent 3-5 days in the arctic tundra and a forest on a low-calorie diet (600 kcal/day), with limited fluid intake wearing clothing and special gear with various heat-insulating properties. As a result of these studies, changes inherent in cold stress were demonstrated and, in our opinion, they could serve as pathophysiological criteria of endurance of survival conditions. They include grade 1-2 chronic hypothermia with more than 100 kcal decrease in heat content, dehydration to 7%, hemodynamic disturbances with signs of orthostatic instability and relative hypoglycemia of up to 50-60 mg%.

Analysis of objective parameters of the thermal state of the subjects and their heat sensations revealed that 35.0°C should be considered the permissible level of drop of body temperature, since it is at this temperature that there is decompensation of adaptive mechanisms of heat regulation, and one observes drastic and persistent drop of superficial temperature of the limbs. When the skin temperature of the foot drops below 10.0°C the chill syndrome may appear, and one observes loss of cutaneous sensibility. Accumulation of condensate in special airtight gear, particularly in the region of the lower extremities, would create the conditions for local cooling and subsequent frostbite.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

Dehydration, which occurs in the Arctic without precursors and visible worsening of well-being, is associated with increase in viscosity of blood and decreased delivery of blood to peripheral tissues, which unquestionably lowers endurance of low ambient temperatures. The main causes of dehydration are increase in sodium excretion in urine, diminished fluid intake because of the negative attitude toward cold water obtained from snow, as well as the large loss of moisture from the pulmonary tract when breathing cold air.

Studies of hemodynamics against the background of chronic cooling and dehydration revealed that virtually all subjects presented signs of orthostatic instability by the end of the 3-5-day experiments, which were manifested by a drop of pulsed systolic pressure and minute blood volume, increased peripheral resistance to blood flow. Subjectively, there were reports of dizziness, palpitations, dyspnea and muscular fatigue. In two cases, we observed a syncopic state on the 3d day. It must also be noted that hemodynamic disturbances diminish drastically man's active survival functions and exposure time.

FOR OFFICIAL USE ONLY

RESUSCITATION AND ANESTHESIOLOGICAL PROBLEMS OF SPACE MEDICINE

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 125-126

[Article by L. L. Stazhadze, V. V. Bogomolov and I. B. Goncharov]

[Text] The role of medical support of LIK [expansion unknown] is increasing with increasing in duration and complexity of programs of manned space flights. For the last few years there has been active work on special problems of resuscitation and anesthesiological support as related to the theoretical probability of life-endangering conditions at different stages of a space flight.

Problems of anesthesiology for probable acute states in the early readaptation period were studied in model experiments involving 49 days of antiorthostatic hypokinesia (AOH). The distinctions of the effects of single component anesthesia--ether, fluorothane, thiobarbiturates, sodium oxybutyrate, ketalar and neuro-analgesia agents--were studied on 15 male subjects 24 to 35 years of age. We demonstrated a number of undesirable clinical effects of the tested monoanesthetics, which were related both to the pharmacodynamic distinctions of the anesthetics and reactivity distinctions of the subjects in the early readaptation period.

On the basis of analysis of the results of our experiments, an optimum form of anesthesia was developed for the early readaptation period--multicomponent balanced anesthesia, the main content of which is the use of anesthetics and neuroleptics in subanesthetic doses, which provide all the necessary elements of general anesthesia under conditions of muscle relaxation and optimum modes of artificial ventilation of the lungs. The choice of anesthetics and corrective infusion therapy is determined on the basis of the nature of the main pathology, for which anesthesia is administered, as well as with consideration of functional changes in the body's systems as a result of the effects of space flight factors. The proposed method of anesthesia has been successfully tested in the early readaptation period following 182 days of AOH, in two groups of subjects.

In addition to refinement and standardization of traditional methods of resuscitation and anesthesiological care, a search is being made for basically new ways and means of emergency care which are not in wide use in clinical resuscitation practice. In this respect, experimental and clinical development of such methods of resuscitation and anesthesiology as conduction forms of anesthesia (peridural anesthesia, acupuncture), electroneurolepsy, as well as physical methods

FOR OFFICIAL USE ONLY

in the system of emergency care, merit attention: external cardiosynchronized counterpulsation, electrophrenic respiration, local hypothermia and hyperbaric oxygenation. The theoretical and first experimental and clinical studies in this direction warrant consideration thereof as promising in the system of refinement of medical support of manned space flights.



FOR OFFICIAL USE ONLY

EFFECT OF HYPOKINESIA ON REGIONAL REDISTRIBUTION OF BLOOD IN THE PRESENCE OF TRAUMATIC SHOCK

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 126-127

[Article by V. F. Lysak]

[Text] Our objective was to study changes in delivery of blood to organs, tissues and different parts of the body in the presence of traumatic shock induced against the background of 7 days of hypokinesia.

Experiments were conducted on male albino rats weighing 230-250 g. Hypokinesia was produced by putting the animals in individual, small box-cages for 7 days. Traumatic shock was simulated according to Cannon. Changes in absolute and relative blood content were determined in the erectile and torpid stages of traumatic shock, concurrently in 38 organs, tissues and parts of the rat body, into which the entire vascular system was divided. The method of recording regional redistribution of blood with the use of radioactive tracers of formed elements and components of blood plasma was described previously (O. A. Kovalev et al., 1974, 1975). The severity of the animals' condition was determined on the basis of changes in several parameters of systemic hemodynamics and carbohydrate metabolism.

The erectile phase of traumatic shock, against the background of 7-day hypokinesia, was characterized by excitement of the animals, elevation of arterial pressure and increase in heart rate. The change in parameters of carbohydrate metabolism were indicative of development of hypoxia, already at this initial stage of shock. Circulating blood volume diminished reliably. Regional redistribution of blood was determined by the drastic increase in blood at the site of trauma and, to a lesser extent, in the myocardium. There was substantial decrease in delivery of blood to the liver, small and large intestine, stomach, kidneys, adrenals, pancreas and integument of different parts of the body.

At the torpid stage of shock, when arterial pressure dropped to 40 mm Hg, there was a drastic increase in amount of incompletely oxidized products of carbohydrate metabolism in blood, indicative of development of a severe form of hypoxia. The redistribution of blood was characterized by displacement from the liver and integument of the forelegs to the brain, in muscle and osseous tissues of the head, neck, chest, abdomen and pelvis minor, anterior limbs, to the scalp and chest. Survival time constituted 4 h, whereas intact rats (without prior hypokinesia) survived for over a day following trauma of the same severity, without treatment.

FOR OFFICIAL USE ONLY

Analysis of the obtained results on regional redistribution of blood and changes in parameters of systemic hemodynamics and carbohydrate metabolism indicates that relatively brief, 7-day hypokinesia altered appreciably reactivity of the organism and diminished its resistance to severe shock-inducing trauma. For this reason, it may be assumed that treatment of shock occurring against the background of prior hypokinesia would require additional shock-treatment measures, as compared to conventional ones.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

THE PHENOMENON OF CONVERGENCE OF CERVICOLABYRINTHINE IMPULSATION ON MECHANISMS OF THE SPINAL REFLEX SYSTEM AND ITS SIGNIFICANCE TO THE CHARACTERISTICS OF VESTIBULOCEREBRAL RELATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 128-129

[Article by A. I. Yarotskiy]

[Text] Complex structures of synchronous afferentation, which are activated under the influence of accelerations and changes in position of the body and its segments are of great functional significance to vital functions of the human body as a whole.

The cervicolabyrinthine complex of perturbations, in the form of rapid turning of the head at the rate of two movements per second for 5 s, is associated with the phenomenon of convergence, which is demonstrable on the level of the spinal reflex system with 20 successively induced series of patellar reflexes, which were recorded by means of a sensor that transformed mechanical energy into electrical and a high-speed N-320-1 automatic recorder. The cervicolabyrinthine-spinal phenomenon of convergence reflects the polymodal activity of motoneurons of the patellar reflex arc, which enables us to determine the nature of background activity of the functional system under study and prognostic value of this information. Typological signs of converging intersystemic relations between the vestibular and cervicopatellar proprioceptive analyzer complex are demonstrable, and they consistently disclose the possible reactive levels of activation, depression, stability or alternation of functions of the genetically formed spinal reflex system. The above-described phenomenon of vestibulo-cervico-spinal convergence may be used as a functional diagnostic test to assess the processing activity of the central nervous system in the presence of changing vestibular and cervicospinal proprioceptive afferentation. The validity of such a thesis is consistent with the studies of O. G. Gazenko and N. A. Chekhonadskiy (1973), who isolated neurons in vestibular nuclei, which had the function of "summators," as well as the results of studying the physiological mechanisms of the effects of head movement on the body during flight in a revolving spacecraft, which were described by F. A. Solodovnik and L. M. Vorob'yev (1973). Studies of the processing function of the central nervous system in response to specific perturbing influences are important primarily from the practical point of view, in the aspects of aviation and space biology and medicine, since they pertain to the disclosure of decisive mechanisms of formation of adequate intrasystemic and

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

intersystemic relations in the human body on the ground and in space flight. Some possibilities are being offered for further refinement of expert evaluation of flight work, as well as ways and means of functional training of the relevant groups of flight personnel.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

CHARACTERISTICS OF COORDINATING 'ADJUSTMENT' OF THE CENTRAL NERVOUS SYSTEM IN STUDIES OF POSTURAL REACTIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 129-130

[Article by A. I. Yarotskiy, V. P. Bezverkhov, N. I. Ivanova, V. D. Yarotskaya and R. N. Salimova-Prokopenko]

[Text] In view of the thesis of P. K. Anokhin (1975), according to which the function of man standing erect is viewed as a classical example of mutually cooperative organization of a set of components of a functional system with a distinct criterion of its useful result, we effected experimental and applied modeling of structural variants of system formation during maintenance of equilibrium of the body with variation of the body's center of gravity, reduction of supporting area and graded vestibular stimulation without visual orientation.

We examined more than 500 people with different structures of motor skills, in order to differentiate between the correlations of degree of development of equilibrium as a function of the nature of motor activity.

We took into consideration the duration of maintaining body equilibrium and physiological tremor of the head, recorded synchronously in the sagittal and frontal planes of space with and without visual orientation.

Variational statistical analysis of the duration of maintaining equilibrium in a series of successive tests revealed that there was a wide range of individual differences in body equilibrium functions of physically conditioned people, which is indicative of the high degree of differentiation of coordinating set of the central nervous system in regulating postural reactions and of the informativeness of the method of successive combined modeling of system-forming effects of the functional system of maintaining equilibrium of the body. It was established that there was a high system-forming effect of the optimum motor activity on development of functions of equilibrium.

Use of our original procedure for synchronous registration of head tremor in two spatial planes under various biomechanical and physiological conditions revealed the diagnostic importance of analyzing the dynamics of frequency, amplitude and rhythm of oscillating head movements. We demonstrated adequate and inadequate orientation of the compensatory system and alteration of regulatory system of head tremor in the course of simulating conditions that make it difficult to hold the body in vertical position.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

It is desirable to use the set of successive differential tests of body equilibrium, stability of vestibular somatic reactions with the characteristics of physiological tremor of the head to study motion sickness and as a method of functional diagnostics of coordinating "adjustment" ["fine tuning"] of the central nervous system in the practice of aviation and space medicine and biology.

FOR OFFICIAL USE ONLY

STUDY OF THE PATHOGENESIS OF MOTION SICKNESS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 130-131

[Article by G. L. Komendantov, N. A. Razsolov, A. G. Bystrova, I. S. Maysheva and V. D. Yustova]

[Text] Determination was made of the role of etiological and pathogenetic modeling in the study of the pathogenesis of motion sickness (MS), and the gnosiological significance of dialectical unity of the essence of MS was demonstrated: pathogenesis and phenomena--clinical manifestations. The systems approach made it possible to establish new patterns in the pathogenesis of MS, to determine the role of spatial (polyanalyzer) and time summation of reactions in afferent and efferent systems and irradiation of stimulation from specific nerve structures.

Systemic investigation of human circulation established that the pathogenesis of cardiovascular disorders associated with MS has three stages: 1) defense-adaptive; 2) compensatory and 3) pathological regulation. These disorders are based on the contradiction between the increased cardiac output and diminished venous return. Development of cardiovascular reactions in the presence of MS is a reflection of the process of summation in the effector element of self-regulation.

A method was developed for quantitative evaluation of the process of summation of righting reflexes (according to their autonomic component) during sea sickness. When statokinetic stimuli are delivered to intact animals, they develop the first stage of sea sickness (faster heart rate) and with increase in number of stimuli they develop the second phase (slowing of heart rate). Administration of sodium hydrocarbonate to intact animals retarded the summation process, whereas this agent had no effect on summation in animals with bilaterally resected superior cervical sympathetic ganglia. Summation of the above reactions to rocking was not demonstrated in labyrinthectomized rabbits.

Use of drugs as a "pharmacological scalpel" enabled us to define the role of mediatory systems of the organism in the pathogenesis of MS and to establish that, depending on the criteria of evaluating efficacy, a positive preventive result can be obtained with adrenergic, adrenolytic, cholinolytic, antihistamine, GABA-ergic and adaptogenic agents. The developed "pharmacological scalpel" method made it possible to obtain new data on the process of summation of reactions associated with seasickness and to validate the search for effective drugs for the prevention and treatment of MS.

FOR OFFICIAL USE ONLY

The following served as criteria of efficacy in our tests of the drugs: duration of latency period of motion sickness, severity of autonomic reactions, as well as change in equilibrium function, which was assessed by the method of E. Graybiel (1975). It was established that combinations of drugs were more effective. The effective drugs prolonged the latency period of MS; they had different effects on equilibrium function and diminished the severity of autonomic reactions. When searching for such drugs, it is imperative to take into consideration the above-mentioned criteria of efficacy.



FOR OFFICIAL USE ONLY

STUDY OF THE PATHOGENESIS OF THE SPACE FORM OF MOTION 'SICKNESS'

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 132-133

[Article by A. M. Genin, I. B. Kozlovskaya, I. S. Krikun and V. V. Usachev]

[Text] A study was made of the role of the hemodynamic factor and certain visual situations in endurance of vestibular loads in order to explore the mechanisms of development of the space form of motion "sickness." The cardiovascular changes inherent in the early stage of weightlessness was reproduced by antiorthostatic positions of different angles ( $-6^\circ$ ,  $-20^\circ$  and  $-30^\circ$ ) and for different periods of time (2 h with  $-20^\circ$  and  $-30^\circ$  positions, 7 days with  $-6^\circ$ ). Situations of vestibulo-visual and vestibulo-oculomotor discrepancy were created by delivering different visual stimuli (by means of a self-contained chamber put on the subject's head) during rotation. In all, we conducted 223 experiments involving 42 subjects.

The results of these studies revealed that staying in antiorthostatic position, which caused marked changes in systemic and intracranial circulation (displacement of blood mass to the head, increased cardiac output, labored venous efflux from the cranium, diminished orthostatic stability) had no adverse effect on endurance of vestibular loads; in some cases, individuals who were not conditioned for low levels of acceleration presented a substantial elevation of level of vestibulo-vegetative stability (VVS). There was also virtually no change in reactivity and excitability of the vestibular system, according to the results of the galvanic and caloric tests (G. I. Gorgiladze, Yu. V. Kreydich, G. I. Samarin, 1977).

Fixing the eyes on a stationary point (delivered at a distance of 30 cm from the eyes) during rotation led to a reliable decrease of VVS and significant extension of the aftereffect period (1 day or more). Discontinuation of fixing (delivery of a field without reference points) or elimination of the visual system of fixation (foveal vision) restored the initial VVS parameters.

Analysis of experimental data and those in the literature warrants the assumption that development of vestibulovegetative disturbances in the described visual situations could be due to the greater difficulty of tracking tasks that are ordinarily performed automatically through a mechanism of rigid vestibulo-oculomotor reactions (Cavshar et al., 1976; Ito, 1972, and others). and a discrepancy between vestibular and visual input signals on the level of the nuclei of the vestibular system (vestibular nucleus, thalamic vestibular relay and others), the neurons of

FOR OFFICIAL USE ONLY

which normally receive equivalent [with equal meaning] labyrinthine, visual and oculomotor afferentation (Dichgans et al., 1972; Azzena et al., 1974, and others). In turn, disintegration of nuclear function in the vestibular system could alter appreciably the systems of autonomic and, in particular, cardiovascular regulation through the mechanism of direct vestibulospinal and vestibulo-cerebello-spinal connections, the existence of which is presently confirmed by a number of studies (Daba et al., 1972; M. I. Gurevich et al., 1973, and others).

The increase in VVS observed in subjects who were not conditioned for low levels of acceleration (in brief antiorthostatic position) indicates that the hemodynamic changes attributable to vestibular factors can be curbed by changes in the cardiovascular system, which develop in antiorthostatic position. Indeed, in the presence of severe forms of motion sickness, we demonstrated a substantial decrease in pulsed filling of intracranial vessels.

FOR OFFICIAL USE ONLY

PATHOGENETIC BASIS FOR DEVELOPMENT OF MOTION SICKNESS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 133-134

[Article by F. A. Solodovnik]

[Text] Formation of the set of symptoms of motion sickness is probably related to the function of the limbicoreticular complex, which plays an important role in regulating autonomic functions of the body and adaptation of the organism to the environment.

Prolonged stimulation of receptors of different afferent systems and, mainly, receptors of the vestibular analyzer is the causative factor of development of motion sickness. But motion sickness can only develop if a certain condition is present, which refers to man's special predisposition for motion sickness. This predisposition is probably based on constitutional deficiency of expressly the limbicoreticular complex.

One of the probable and promising directions of investigation of motion sickness could be to study the functional distinctions of the limbicoreticular complex of individuals with a predisposition for sea sickness. The obtained results of the studies would define some aspects of the pathogenesis of motion sickness which, in turn, would make it possible to outline basically new approaches to vestibular screening, prevention and treatment of seasickness.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

SOME CLINICOPHYSICAL ASPECTS OF VESTIBULAR DISORDERS DURING SPACE FLIGHTS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 134-136

[Article by I. I. Bryanov, E. I. Matsnev, B. I. Polyakov and I. K. Tarasov]

[Text] An analysis was made of the clinicophysiological distinctions of sensory and vestibulovegetative disorders in 66 cosmonauts who had participated in orbital flights. The results of ground-based vestibulometry were compared to the reactions in weightlessness.

Vestibulovegetative disorders, illusional sensations and elements of disorientation were present in about one-third of all Soviet cosmonauts. Symptoms of motion sickness (MS) appeared in weightlessness and persisted at different times of the first stage of the flight, from the first minutes and hours to the 6th-7th day. An increase in motor activity, especially head movements, optokinetic stimuli, intake of food, altered schedule for the day and fatigue accelerated development of vestibulovegetative disorders, whereas emotional tension and performance of important work operations diminished signs of discomfort. Sleep improved well-being substantially.

Polymorphism, significant variability of intensity and duration were inherent in illusions of perception of spatial coordinates.

In the postflight period, most cosmonauts presented disturbances referable to postural equilibrium function, statokinetics, and some of them presented varying degrees of vestibulovegetative disorders.

Analysis of clinical manifestations of vestibular disorders during space flights revealed that "sensory conflict" was an important etiological factor of development of MS in weightlessness. Redistribution of fluids in a cranial direction and difficulty of venous efflux from the head probably also played some role as a contributing factor; this can be considered also as an element of "sensory conflict" (unusual afferentation from different interoceptors, including sensory structures in the brain proper and its meninges).

A comparison of the data obtained from ground-based vestibulometry to the nature of inflight reactions revealed the prognostic significance of the initial level of vestibulovegetative stability, the level that was demonstrated at the very first stage of screening, before starting vestibular training. There was close

FOR OFFICIAL USE ONLY

## FOR OFFICIAL USE ONLY

to zero probability of development of inflight vestibulovegetative disorders among individuals with an initially high (excellent) level of stability.

Ground-based vestibular training diminished the probability of development of MS in weightlessness, particularly in individuals with initially good stability. During training, it is imperative not only to take into consideration its efficacy, but individual distinctions pertaining to achievement and maintenance of the conditioning effect when exposed to various exogenous and endogenous factors. Complex training also helps cosmonauts consciously regulate their motor activity during the first days of a flight in order to avoid reaching the point of marked disorders. In the opinion of most cosmonauts, preflight vestibular conditioning is desirable.

The foregoing is indicative of the importance of the MS problem in space medicine and of the need for continued coordinated effort in the study of its etiology, pathogenesis, methods of prevention and therapy.

One of the least studied questions is referable to the causes of individual differences in susceptibility to MS. As a result of a series of studies conducted for the last few years (B. I. Polyakov et al., 1968-1978), it was shown that susceptibility or, on the contrary, resistance to MS is significantly determined by the distinctions of neurohumoral regulation of autonomic functions. These distinctions are manifested in the initial clinicophysiological state, and they can be demonstrated by a set of functional diagnostic methods.

On the whole, individuals resistant to MS are characterized by prevalence of ergotropic mechanisms of regulation, due to greater activity and reserve capabilities of their adrenosympathetic system. However, individuals susceptible to MS present relative trophotropic prevalence, which is related to relatively lower activity and reserve capabilities of the adrenosympathetic system, and not to increased tonus of central parasympathetic mechanisms.

Some encouraging results were obtained from studies of the efficacy of various agents for the prevention and treatment of MS, with regard to cavinton (alkaloid of anovincamine), a product that normalizes cerebral circulation and cerebral metabolism (D. Bodo et al., 1978). It was also established that use on the central nervous system of pulsed electric current in the modes generally used for electroanalgesia attenuates the vestibulovegetative disorders with repeated exposure (B. I. Polyakov, 1979), which is probably due to acceleration of adaptive processes. Beneficial results were also obtained with a combination of electroanalgesia and pharmacological agents (E. I. Matsnev et al., 1979).

In view of the specifics of the work done by spacecraft crews, it is deemed desirable to continue testing this method as a possible means of alleviating and shortening the period of adaptation to weightlessness, as well as attenuating vestibulovegetative disorders at the early stage of the flight.

FOR OFFICIAL USE ONLY

FUNCTION OF VESTIBULAR ANALYZER IN THE PRESENCE OF ALTERED CEREBRAL CIRCULATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZYNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 136-137

[Article by Ye. P. Tikhomirov, G. I. Pavlov and V. Ye. Grishanov]

[Text] Vestibulovegetative reactions are not uncommon in cosmonauts during space flights. Several hypotheses have been expounded concerning their genesis. The authors of one of them (I. I. Bryanov et al., 1975) adhere to the view that the redistribution of total circulating blood volume in weightlessness, which has become a generally recognized fact, and consequent set of hemodynamic changes are the initial factor.

We conducted two series of experiments to examine the effect of redistribution of blood from the upper part of the body to the lower on the functional state of the vestibular analyzer: 1) determination of thresholds of sensitivity of the vestibular analyzer to linear accelerations according to the subjects' sensations of movement on an acceleration stand while creating negative pressure over the lower half of the body [LBNP] constituting 30, 40, 45, 50, 55 and 60 mm Hg using a Chibis suit; 2) recording nystagmus while creating angular accelerations on an electric revolving stand, in rabbits with unilateral and bilateral ligation of the carotid artery. In both series of studies, rheoencephalographic and electrocardiographic data served as a control.

In the first series, 70 experiments were conducted on 17 subjects. These studies revealed that sensitivity of the vestibular analyzer was unchanged with -30 mm Hg, and that it increased with 40, 45, 50, 55 and 60 mm Hg. Thus, while sensitivity of the vestibular analyzer constituted a mean of  $0.011 \text{ m/s}^2$  in control experiments, it was  $0.0065 \text{ m/s}^2$  with creation of negative pressure.

In the second series, 94 experiments were conducted on 10 rabbits. They revealed that the amplitude of the REG [rheoencephlaogram] diminished by 20-30%, as compared to the base level, immediately after ligating one of the carotid arteries, and nystagmus lasted an average of 12.5% less; after ligation of both carotid arteries, there was a 50% decrease in REG amplitude and 22% decrease in duration of nystagmus. Analogous data were obtained with regard to amplitude of nystagmus. As for the frequency of nystagmic reactions, it changed insignificantly and the readings were unreliable.

The results of our studies indicate that the functional state of the vestibular analyzer depends on redistribution of mass of circulating blood.

FOR OFFICIAL USE ONLY

STATOKINETIC STABILITY AND FITNESS OF FLIGHT PERSONNEL

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 138-139

[Article by V. I. Kopanev]

[Text] Statokinetic stability refers to man's ability to retain stable fitness for work, spatial orientation and equilibrium function, implemented by an optimum level of regulation of physiological functions in the presence of statokinetic stimuli, which appear during active and passive movement in space (N. N. Lozanov, G. L. Komendantov, V. I. Kopanev and others).

A distinction is made between several special forms of statokinetic stability, depending on the mode of movement in space: orthostatic, clinostatic, static, antigravity, kinetic and optokinetic.

We studied the correlation between static (holding a vertical position), kinetic (during exposure to Coriolis accelerations) and optokinetic (exposure to optokinetic stimuli) forms of statokinetic stability, on the one hand, and man's fitness on the other. The latter was assessed according to ability to retain an erect position (somatic reaction), severity of vegetative and psychosensory reactions, as well as parameters of functional state of some analyzers. As a result of these studies, it was established that man's fitness is directly related to statokinetic stability. There was appreciable deterioration of fitness in the event of diminished or completely impaired statokinetic stability (I. A. Kolosov). The studies of I. K. Tarasov, V. Ya. Lopukhin, M. P. Yefremenko, I. L. Litmanov, S. G. Mel'nik and D. T. Lukashchuk, conducted under our guidance, defined the means of enhancing statokinetic stability by means of purposeful physical training, specific and nonspecific forms of training [conditioning] and drugs. As a rule, the efficacy of these procedures was manifested by an increase in man's general fitness and, in some cases, professional fitness as well. The obtained data warrant the conclusion that efforts to enhance man's fitness without consideration of statokinetic stability are unlikely to lead to positive results. An optimum solution to the problem of improving the fitness of flight personnel is possible only if these two problems are considered together.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

REFLEX THERAPY AS A POSSIBLE MEANS OF ENHANCING RESISTANCE TO CORIOLIS ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 139-140

[Article by Ye. M. Yuganov, L. L. Khundanov and G. I. Pavlov]

[Text] Acupuncture (zhen-jiu therapy) has a distinct therapeutic effect in the treatment of a number of pathological states and, in particular, curbing attacks of Meniere's disease and vestibulopathy (I. B. Soldatov, N. S. Khrappo, 1977).

For this reason, we tried to use acupuncture to enhance man's endurance of vestibular stimuli and prevent vestibulovegetative disorders.

For this purpose, we conducted studies of the effects of acupuncture on man's endurance of continuously building up Coriolis accelerations (CCA), reproduced by a well-known method (S. S. Markaryan, Ye. M. Yuganov, Sidel'nikov, 1966).

The study of vestibular stability was stopped after 15 min of exposure to Coriolis accelerations or at any time that retching appeared in the presence of pallor and hyperhidrosis of the facial integument. We recorded the time of appearance of these reactions.

The following points were used for acupuncture: ren-zhun, ya-men, ting-gong, he-gu, nei-guan. Acupuncture was performed once or for 10 days. There were 14 participants in the experiments, and they were divided into three groups according to degree of vestibulovegetative stability: 1) with low stability (up to 2 min); 2) with average stability (3 to 10 min) and 3) with high stability--at least 15 min (control group).

It was established that endurance of CCA increased by 1.3 times after single acupuncture, there were less marked signs of nausea and the postrotation period had a milder course.

Prolonged (up to 10 days) acupuncture increased CCA endurance time by 2-2.5 times, and this effect lasted for 7 days. A beneficial effect was observed in all cases without exception (except the control group), but the most substantial results were noted in the first group, where CCA endurance time increased by 4-5 times. In all of the subjects, symptoms of gastrointestinal discomfort occurred at a later time, and nausea was less marked in the aftereffect period.

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

To determine the mechanisms of action of acupuncture, a series of studies was conducted with concurrent use of acupuncture and an herb infusion recommended by Tibetan medicine to improve the general tonus of the body. In this case, the effect of acupuncture extended for up to 14-17 days.

In the next series, before acupuncture and after a 10-day course thereof, determination was made of the thresholds of the vestibular analyzer for linear accelerations. The thresholds were evaluated on the basis of the subjects' perception of the direction of movement of the stand, while the lowest level of acceleration served as the criterion of sensitivity of the otolith system. We found that there were no changes in thresholds of perception of accelerations after acupuncture.

These findings enabled us to expound the hypothesis that acupuncture has a non-specific effect on vestibular stability.

Thus, our studies demonstrated the following: 1) the acupuncture method elicits a rather substantial attenuation of vestibulovegetative reactions to Coriolis accelerations; 2) the effect of acupuncture is not determined by its specific action, but apparently by depression of the vomiting reflex against the background of improved general tonus of the human body.

FOR OFFICIAL USE ONLY

'SANOGENESIS' OF VESTIBULAR DISORDERS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 140-141

[Article by O. Ya. Plepis]

[Text] Comprehensive attention is being given presently to the study of the pathogenesis of vestibular disorders after exposure to gravity forces, while the problem of sanogenesis is not sufficiently discussed.

We use the term, "sanogenesis," to refer to the dynamic set of defense and adaptive mechanisms (physiological and pathophysiological) that appear at the premorbid stage, which develop throughout the morbid process and are directed toward restoration of impaired self-regulation of the vestibular system and the entire organism.

Questions of sanogenesis of vestibular disorders should be discussed on the basis of the conception of functional element of organs and tissues formulated by A. M. Chernukh. Functional element refers to a complex microsystem consisting of cells and noncellular elements of an organ (in this case, the cochlear meatus of the labyrinth), located around a microcirculatory unit (vascular plane of the cochlear meatus) and united by regulatory neurohumoral mechanisms. This conception broadens our concepts of development of labyrinthine hydrops and the role played there by the distinctions of neural trophics of tissue, microcirculation and transcapillary exchange in the labyrinth of patients with vestibular disorders.

The problem of sanogenesis is just as complex as that of pathogenesis, and for this reason it can be considered on different levels of recovery.

The process of sanogenesis undergoes stages of equilibration of neuroendocrine functions, normalization of self-regulation of the cardiovascular system and normalization of general homeostasis of the body. The proposed scheme of sanogenesis of vestibular disorders makes it possible to outline the means of preventing and treating them.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

PHARMACOLOGICAL PREVENTION OF DISORDERS OCCURRING UNDER THE CUMULATIVE EFFECT OF ACCELERATIONS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERNETSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOMSICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 141-143

[Article by I. I. Voinova and Ye. Ya. Kaplan]

[Text] We know that pathological reactions of vestibular origin, which worsen the fitness of special personnel, may occur under the cumulative effect of accelerations going in different direction, differing in magnitude and nature. For this reason, prevention of such disturbances is of practical importance in aerospace medicine.

One of the important directions of protection against motion sickness is to use pharmacological agents. It is difficult to find the optimum agents against seasickness because of the diversity of biological objects used, lack of adequate models and informative parameters, according to which one could judge the efficacy of newly synthesized compounds.

Our objective was to investigate the possibility of using dogs and simulating motion sickness in them to assess the antikinetic properties of drugs.

Kinetosis was modeled in mongrel and purebred beagle dogs by means of long-term exposure to angular accelerations in different directions, of  $45$  and  $180^\circ/\text{s}^2$  and Coriolis accelerations, which occurred upon simultaneous rotation of the animals in two mutually perpendicular planes, horizontal and vertical, at velocities of  $180$ ,  $90$ ,  $60$  and  $45^\circ/\text{s}^2$ . The state of kinetosis was evaluated in the animals on a grade scale that we proposed (I. I. Voinova, Ye. Ya. Kaplan, Ye. M. Yuganov, E. A. Rudzit, 1976). We studied the effects on onset of vestibular disorders of the following antikinetic agents: aminalol, scopolamine, dedalon, liquid eleuterococcus extract, phenamine and a mixture consisting of aminalol, liquid eleuterococcus and caffeine. As a control, we compared the effects of apomorphine, copper sulfate, saline and 5% aqueous glucose solution, which are neutral or have an adverse effect on motion sickness, on animals submitted to cumulative accelerations.

It was shown that disorders occur faster and are more marked in purebred and mongrel dogs under the influence of Coriolis accelerations than angular ones. Preliminary administration of apomorphine and copper sulfate enhanced the signs of kinetosis [kinesia] and hastened its onset. Glucose and saline had no appreciable effect on the course of motion sickness in dogs. All of the tested agents,

FOR OFFICIAL USE ONLY

which have antikinetic action in man, attenuated or prevented development of motion sickness symptoms in the animals. A mixture of aminalol, eleuterococcus and caffeine had the most marked antikinetic effect. Aminalol, caffeine, scopalamine and dedalon prevented development of motion sickness in the mongrels. They attenuated its manifestation in the purebred dogs. Of the tested antikinetic agents, aminalol and dedalon had a more marked preventive effect on the beagles.

Our results indicate that there is a parallel between the antikinetic effects of the tested pharmacological agents on the selected biological object and on man. This warrants the recommendation that the motion sickness model in dogs can be used for quantitative evaluation of the antikinetic effects of pharmacological agents.

FOR OFFICIAL USE ONLY

PRINCIPLES INVOLVED IN THE APPROACH AND CHOICE OF AGENTS FOR THE PREVENTION AND TREATMENT OF MOTION SICKNESS IN ORBITAL FLIGHT

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOUZHNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 143-144

[Article by P. I. Syabro, T. N. Krupina, I. P. Neumyvakin and L. G. Polevoy]

[Text] In our opinion, the following are the chief causes of inadequate efficacy of pharmacological and other preventive measures against motion sickness in space flight: 1) vestibulosensory, motor and autonomic reactions of the organism to afferent signals of the statokinetic functional system are formed with the participation of structures of the brain stem, whose neurons are polyfunctional and provide for self-regulation of vital functions. Evidently, partial or total elimination of some element of self-regulation with pharmacological agents in itself leads to discoordination of the system. 2) With development of motion sickness, there is a change in conditions for dissolution and absorption of pharmacological agents in the gastrointestinal tract. 3) In weightlessness there is faster manifestation of autonomic reactions, change in reactivity of the organism to accelerations upon moving the head and body, as well as to intake of pharmacological agents.

The measures for prevention and treatment of motion sickness could be based on all sorts of physiological mechanisms of control, in the form of creation of dominant states of nerve centers having a conjugate relationship to vestibular and autonomic parts of the brain stem. The rapid extinction of the vomiting reflex by inhalation of ammonia fumes, which we observed, as well as the high efficacy of caramel candy or chewing gum against experimental seasickness (I. I. Syabro et al., 1973), is convincing evidence of the efficacy of such measures.

We could recommend chewing and sucking on caramels, and chewing gum, both separately and together with elements of complex pharmacological agents containing substances that affect central structures of the central nervous system, as well as the periphery, which induce a spasmolytic effect, for the prevention and treatment of motion sickness.

In addition, it is desirable to use complex pharmacological agents by inhalation in the form of aerosols and, for severe signs of seasickness, drugs in tube-syringes for hypodermic injection.

FOR OFFICIAL USE ONLY

Development of individual programs of electroacupuncture and autogenic training, the efficacy of which must first be tested on the ground, appears to be promising as the method of choice in prevention and treatment of motion sickness.

An individually developed complex method, involving successive or simultaneous use of physiological, physiotherapeutic and combined pharmacological agents, may be the optimum means of preventing and treating motion sickness in cosmonauts during space flights.

FOR OFFICIAL USE ONLY

COMPLEX METHOD FOR ENHANCING VESTIBULAR STABILITY

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 144-145

[Article by V. N. Alekseyev, I. K. Tarasov and Ye. F. Baburin]

[Text] The problem of improving methods of vestibular conditioning is becoming increasingly important in view of the increased duration of space flights, more complex programs thereof, more intensive training schedules, as well as the possible involvement in training of researchers with low or diminished initial level of vestibular stability (N. N. Gurovskiy et al., 1969). We have developed and tested a complex method to enhance vestibular stability, which consists of using eleuterococcus during passive vestibular training.

The obtained experimental data indicate that use of eleuterococcus in passive vestibular training improves endurance of vestibular loads (cumulative effect of Coriolis accelerations by the method of I. I. Bryanov, 1963); it diminishes significantly manifestation of autonomic reactions and reduces by 1.5-2 times the duration of the cycle of passive vestibular training required to achieve a high level of vestibular stability. This complex method can be used as a high-speed method for enhancing vestibular stability, not only in individuals with a good initial level thereof, but those with diminished or low level.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

ROLE OF VESTIBULAR ANALYZER IN ADAPTATION TO ADVERSE ENVIRONMENTAL FACTORS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 145-147

[Article by N. I. Arlashchenko and Ye. N. Maksimova]

[Text] Conditioning the vestibular analyzer for long-term exposure to centrifugal and Coriolis accelerations, like muscular training, increases the body's resistance to a number of adverse environmental factors, such as changes in barometric pressure, G forces, heat or cold, ether anesthesia and ionizing radiation (Ya. A. Egolinskiy, 1974; A. F. Apenkov, 1974; Yu. G. Grigor'yev, N. I. Arlashchenko et al., 1972; Yu. V. Farber, L. A. Tabakova, 1978). These observations enabled Egolinskiy to refer to the vestibular system as the organ of nonspecific adaptation.

Our objective here was to study the resistance of mice with bilateral labyrinthectomy to cold and ionizing radiation.

Experiments were conducted on 400 male and female CBA mice. Bilateral delabyrinthectomy was performed at the same time under general ether anesthesia, using a modification of the method of M. D. Yemel'yanova (1968) by means of irrigating the middle ear with 10% monoiodoacetic acid. Signs of delabyrinthation, with a marked effort to hold on to a support and chaotic rotation when it is lost, developed within an average of 30 min after the operation. The acute disorders of equilibrium function regressed gradually, and disappeared after 3 weeks.

The condition of the animals with bilateral labyrinthectomy immediately and soon after the operation indicated that loss of labyrinthine function was an extremely potent stressor for them, eliciting the typical adaptation reaction to the new living conditions. Deaths among labyrinthectomized mice occurred mainly on the 7th-10th days after surgery and up to the 3d week, constituting about 20%. The operated animals were used in the experiment no sooner than 40 days after the operation. By this time, the appearance of operated animals was virtually the same as intact ones, with the exception of atactic movements and absence of reactions to sound.

We found that labyrinthectomized animals were more sensitive to adverse environmental factors. Thus, the operated mice died, presenting rigor at an ambient temperature of 12°C, whereas intact animals did not react to such a temperature drop. Exposure of labyrinthectomized mice to radiation revealed that they became more radiosensitive,

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

as indicated by the 100-rad decrease in minimum absolutely lethal dose: from  $LD_{100/30} = 900$  rad for intact animals to  $LD_{100/30} = 800$  rad for labyrinthectomied ones.

Thus, the consequences of excluding such a powerful afferent system as the vestibular analyzer from the general flow of afferent information about the environment indicate the exceptional importance of normal impulsation from the vestibular system to development of the adaptive changes, the need for which arises with changes in physical environmental conditions. Bilateral labyrinthectomy, which induces profound changes in the function of certain parts of the cortex and sub-cortical centers, hypothalamus and reticular formation, leads to heightened sensitivity of operated animals to adverse environmental factors, in particular, to cold and radiation, which is indicative of impairment of adaptation mechanisms in labyrinthectomied animals.

Since the vestibular functional disturbances in animals in weightlessness are analogous to labyrinthectomy, the above findings help arrive at some conclusions with regard to space flight practice. The decline of adaptational capabilities of the organism, which was observed along with loss of labyrinthine function, compels us to pay special attention to the fact that it is not permissible for physical parameters of the environment in a spacecraft to fluctuate, and that adaptogens and other measures directed at enhancing resistance and safeguarding the health of cosmonauts should be used.

FOR OFFICIAL USE ONLY

SIGNIFICANCE OF TROPHICS OF THE VESTIBULAR SYSTEM IN THE MECHANISM OF  
VESTIBULOSOMATIC AND VESTIBULOVEGETATIVE REACTIONS OF EQUILIBRIUM ORGANS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 147-149

[Article by N. I. Arlashchenko]

[Text] Destruction of the trigeminal ganglion elicits a number of profound dystrophic changes in tissues on the side of the operation, such as neuromyopathic keratitis, trophic ulcers on the mucosa and skin of the lips, dystrophic changes in bone marrow, occipital cranial bones and appearance of pathologically increased permeability of the hematoophthalmic barrier (A. V. Lebedinskiy, 1946; N. N. Zayko, 1954, 1970; N. I. Arlashchenko, 1957, 1966).

Destruction of the trigeminal ganglion was performed on 15 rabbits, approaching the sensory ganglion from outside the skull. For 15 days after surgery, we examined labyrinthine functions, after which the animals were sacrificed for histological examination of temporal bone pyramids.

On preparations of the inner ear on the operated side, we observed changes indicative of dystrophic disturbances of the cupular and otolith systems. First of all, there was development of atrophy of sensory cristal epithelium, the cells of which underwent necrotic changes and flaked off. The stroma of the cristae became more homogeneous, and there was appreciable decrease in number of cells. Dystrophic changes, associated with edema of the stroma and layer of nerve elements, were seen in the utricle. Subsequently, there was disintegration and atrophy of all layers of the utricular macula, as a result of which it diminished significantly in size. There was no secretory epithelium on the preparations, since destruction and atrophy thereof occurred much earlier, even before the material was taken. On many preparations there were accumulations of fibrinous masses in the endolymphatic and perilymphatic vestibular spaces. Lamination of endosteum into the cavity of the labyrinth was noted on some preparations. The walls of the membranous labyrinth were collapsed and covered the cristae together with the cupula. Such compression of the membranous labyrinth could be the result of changes in correlation between pressure of endolymph and perilymph, occurring because of destruction of the hemolabyrinthine barrier after the operation. The morphological changes in the inner ear on the unoperated side were less marked.

Labyrinthine functions were markedly depressed by the time the labyrinths were submitted to histological fixing. In response to increasing stop stimuli there

FOR OFFICIAL USE ONLY

## FOR OFFICIAL USE ONLY

was a drastic reduction of nystagmic and respiratory reactions, with prevalence of depression of functional responses of the labyrinth on the side of the operation. The reactions of eye abduction and rotation during simultaneous turns of the head and body of the animal about a longitudinal or transverse axis  $90^\circ$  to the right or  $90^\circ$  up and down from the initial horizontal position revealed in some rabbits vivid differences in degree of abduction and rotation of the eye on the operated and intact sides, whereas in healthy animals these reactions were congruent. General depression of functional responses of both labyrinths, consisting of a decrease in sum of distances between spread digits of both extremities in simulating a jump, as well as decrease in angle of counterrotation of the head with a change in spatial position of the animal, was noted at all times after destruction of the trigeminal ganglion.

Thus, on the basis of our results, we see that sensory innervation on the side of the trigeminal nerve has a direct bearing on trophic state of the labyrinth, and it determines the functional level of the vestibular analyzer. Unilateral destruction of the trigeminal ganglion caused development of atrophy of the equilibrium organ, while the weakening of labyrinthine functions observed at this time was close in degree to the findings with unilateral labyrinthectomy. The existence of sensory afferent innervation of tissues of the membranous labyrinth from the fifth pair of cranial nerves will, apparently, enable us to use a basically different approach to solving problems of prevention and treatment of the vestibulovegetative syndrome, which occurs in weightlessness, by affecting vestibular function through the nonspecific afferent nervous system.

FOR OFFICIAL USE ONLY

EFFECT OF BODY POSITION ON REGIONAL NEUROVASOMOTOR REACTIONS OF PULMONARY CIRCULATION

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 149-150

[Article by A. S. Pogodin]

[Text] A study was made, in experiments on anesthetized cats with intact chest, by the method of regional electroplethysmography of the lungs, of the influence of changes in position of the body on regional vasomotor reactions induced by electric stimulation of the sympathetic and vagus nerves. Electroplethysmographic sensors were used to record electroplethysmograms of different areas while moving the body from horizontal to vertical position and back to horizontal. We made a quantitative estimation of the change in regional filling of the lungs with blood with stimulation of sympathetic (diminished filling) and vagus (increased filling) nerves.

The studied neurovasomotor changes in regional circulation in the lungs occur in the presence of significant changes in systemic and pulmonary hemodynamics, which developed as a result of changing the position of the body. There was marked redistribution of blood in the lungs, in the direction of increase in the direction of gravity. With a change in body position, there was redistribution of regional hydraulic and hydrodynamic loads. Against such a background, there was significant change in quantitative characteristics of regional neurovasomotor effects. However, we failed to demonstrate an unequivocal correlation between body position and magnitude of the neurovasomotor effect. Such a correlation was demonstrable only in certain cases. Thus, with movement of the body from horizontal to vertical position, there were reliable differences in parasympathetic vasomotor effects, in the form of changes in delivery of blood to the dorsobasal regions of the lungs.

The lung regions that experienced a greater regional hydrostatic burden were also found to be more labile with regard to a neurogenic stimulus.

FOR OFFICIAL USE ONLY

FOR OFFICIAL USE ONLY

DISTINCTIONS OF VESTIBULAR REACTIONS AS A FUNCTION OF INTENSITY OF STIMULUS AND STATE OF THE ORGANISM

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) p 150

[Article by Ye. Ya. Kaplan and I. I. Voinova]

[Text] A study was made of vestibular reactions of animals in the presence of altered reactivity induced with pharmacological agents.

The parameters of pulse, respiration rate and nystagmus during exposure to angular accelerations of 45 and 180°/s<sup>2</sup> in different directions and Coriolis accelerations, which appeared when the animals were rotated in two perpendicular planes (vertical and horizontal, at rates of 45 and 180°/s<sup>2</sup>), were studied in experiments on rabbits and dogs.

The vestibulovegetative reactions were more marked, while parameters of nystagmus were less marked in dogs and rabbits under the influence of Coriolis accelerations than angular ones. The severity of somatic and autonomic changes was directly related to the magnitude of angular acceleration.

In the second series of experiments, the animals were exposed to the same factors after administration of various neurotropic agents. Administration of aminalol in a dosage of 100 mg/kg, caffeine and dedalon in a dosage of 10 mg/kg, extract of liquid eleuterococcus in a dosage of 0.2 ml/kg elicited a substantial attenuation of vestibulovegetative and vestibulosomatic changes. Conversely, administration of aminazin and triftazin [stelazine] in a dosage of 10 mg/kg increased the vestibular reactions.

In the third series of experiments, mongrel dogs were submitted to stimulation of the vestibular system following administration of apomorphine. This speeded up significantly the development of seasickness; aminazin and triftazin, given to dogs in a dosage of 10 mg/kg, had a similar effect.

FOR OFFICIAL USE ONLY

BRAIN TISSUE OXYGEN TENSION IN HYPOXIC RATS

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESoyUZNAYA KONFERENTSIYA PO KOSMICHESKOY BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian 1979 (signed to press 23 Apr 79) pp 151-152

[Article by A. V. Ryazhskiy and Yu. S. Galushko]

[Text] Experiments were conducted on 80 albino rats weighing 200-300 g. Determination of  $pO_2$  was made by the polarographic method using special electrodes that consisted of glass-coated platinum needles 100  $\mu$ m in diameter, to which a thin silver tube was attached. The electrodes were coated with a special formula of collodion. Before each experiment, they were calibrated carefully, then inserted in the sensorimotor cortex and immobilized on the skull with phosphate cement.

In the base period,  $pO_2$  of the brain constituted a mean of  $33.8 \pm 0.8$  mm Hg with slight fluctuations of  $pO_2$  of 2-4 mm Hg in both directions. Other researchers reported analogous rhythm of  $pO_2$  in brain tissues (Ye. A. Kovalenko, 1962; N. V. Sanotskaya, 1965). Acute hypoxia was created by raising animals to altitudes of 8, 10 and 12 km in a pressure chamber. The rate of ascent was 40 m/s. They were kept at these altitudes for 10 min.

At 8 km altitude, oxygen tension dropped to  $8.1 \pm 1.5$  mm Hg. We were able to detect distinct hypoxic changes in the animals' behavior: drastical deepening and acceleration of respiration, with occasional signs of excitement. However, after descending from this altitude,  $pO_2$  of brain tissues rapidly returned to the base level, often exceeding it somewhat for the first few minutes after the descent, then to the base level. Severe and distinct hypoxic changes in behavior and function were noted with ascent to 10 and 12 km. Brain tissue  $pO_2$  dropped to  $3.7 \pm 1.6$  and  $0.8 \pm 0.2$  mm Hg. It should be noted that oxygen tension in the brain was below so-called critical levels, i.e., 3-4 mm Hg, at an altitude of 12 km. After descending from these altitudes,  $pO_2$  returned to the initial level within 50-70 s, and in some cases exceeded the latter significantly, rising to 40-50 mm Hg. Such a high oxygen tension persisted for 5-10 min, then reverted to the base level.

In the second series of experiments, we studied the dynamics of  $pO_2$  in the rat brain with slowly progressing hypoxia. The animals were put in a confined container (7 l).

Carbon dioxide was absorbed by silica gel, and pressure was kept at the normal level. The animals died when oxygen content in the container decreased to 4-5%.

FOR OFFICIAL USE ONLY

At this time, brain  $pO_2$  constituted  $3.5 \pm 0.8$  mm Hg, i.e., it reached a critical value.

Thus, it was demonstrated that oxygen tension of brain tissues in the presence of acute hypoxia (for a brief time) can drop below critical values. In the case of slowly increasing hypoxia, animal death occurred when a critical  $pO_2$  was reached in brain tissues.

FOR OFFICIAL USE ONLY

CHANGES IN GAS EXCHANGE AND SOME FUNCTIONAL PARAMETERS IN RATS SUBMITTED TO  
LONG-TERM HYPOKINESIA

Moscow AVIAKOSMICHESKAYA MEDITSINA. VI VSESOYUZNAYA KONFERENTSIYA PO KOSMICHESKOY  
BIOLOGII I AVIAKOSMICHESKOY MEDITSINE. KALUGA 5-7 IYUNYA 1979. CHAST' I in Russian  
1979 (signed to press 23 Apr 79) pp 152-153

[Article by Yu. S. Galushko and A. V. Ryazhskiy]

[Text] Long term hypokinesia (100-130 days) induces an increase in gas exchange  
of rats, and its causes are both an increase in relative body surface with  
retardation of weight gain, as compared to the control, and qualitative changes in  
oxidative tissular processes.

The local rate of oxygen utilization in muscle tissue, as determined in vivo, as  
well as amount of incompletely oxidized products in the urine, are greater in  
hypokinetic rats than the control. A combination of these results with increased  
oxygen uptake by hypokinetic rats is indicative of deficiency of oxidative pro-  
cesses in tissues. This was also confirmed by demonstration of dissociation of  
oxidative phosphorylation in rat tissues under the influence of hypokinesia.

Long-term hypokinesia, lasting up to 100 days, induced progressive and severe  
decrease in physical fitness of rats. Dynamic fitness (swimming time with a  
weight) diminished by 84.5%. Static fitness (time of holding on a vertical rod)  
diminished by 97%, as compared to the control. Deterioration of the rats'  
endurance of physical loads is related both to onset of muscular weakness and  
motor disorders, as well as disturbances referable to oxygen balance in the organism.

Performance of physical exercise by rats after 100 days of hypokinesia was associ-  
ated with a drastic increase in oxygen requirement, by 129%, mainly due to oxygen  
debit which was 576% higher than in the control. The index of recovery, as an  
indicator of the functional state of the organism, dropped appreciably and con-  
stituted 20% of the control value. In the recovery period, by the 30th and 60th  
days following 100-day hypokinesia, there was gradual, but incomplete normaliza-  
tion of the rats' ability to perform physical work. There was also normaliza-  
tion of oxygen balance at rest, and partial normalization with exercise, which is  
indicative of reversibility of the disturbances that had appeared. More than  
2 months were required for complete normalization of fitness and oxygen balance  
of rats following 100 days of hypokinesia.

Endurance of altitude by hypokinetic rats (45th day of experiment) when raised  
to 12 km at the rate of 40 m/s remained the same as in control animals. Endurance

FOR OFFICIAL USE ONLY



FOR OFFICIAL USE ONLY

of slowly increasing hypoxia, as well as hypoxia and hypercapnia in the pressure chamber, was better in hypokinetic rats than control animals. The critical  $pO_2$  in the pressure chamber, at which hypokinetic rats presented respiratory arrest, was 5-10 mm Hg lower than in the control experiment.

There was a decrease in oxygen uptake by rats submitted to increasing hypoxia in the pressure chamber. The dynamics of changes therein, as well as body temperature, heart and respiration rate, were essentially the same in hypokinetic rats as in control animals. These findings, as well as retention of altitude resistance in hypokinetic rats, indicate that they retain the compensatory mechanisms that implement changes in functional systems of the organism as  $pO_2$  drops in the chamber.

COPYRIGHT: Not available

10,657

CSO: 1840/999

- END -